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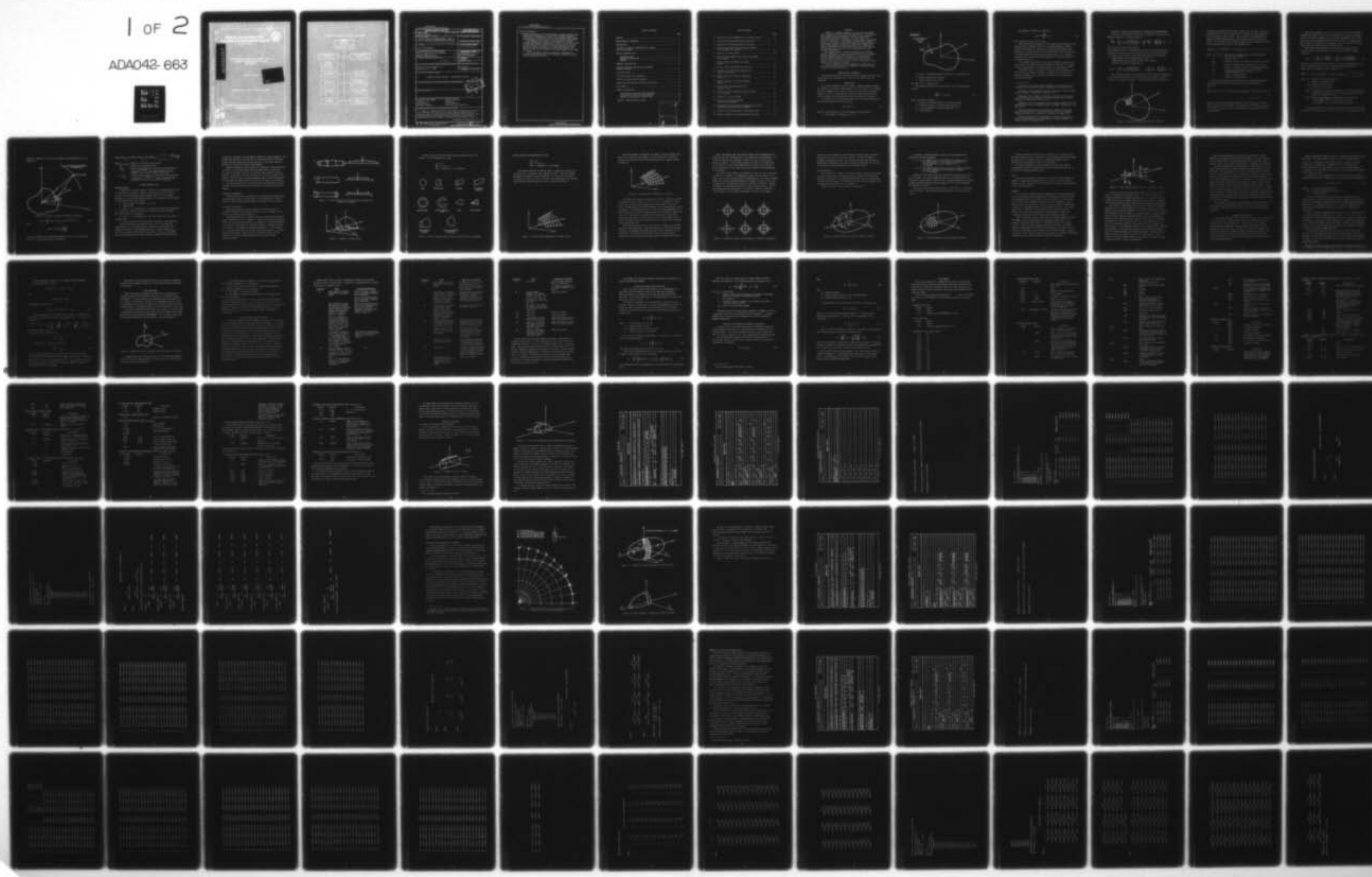

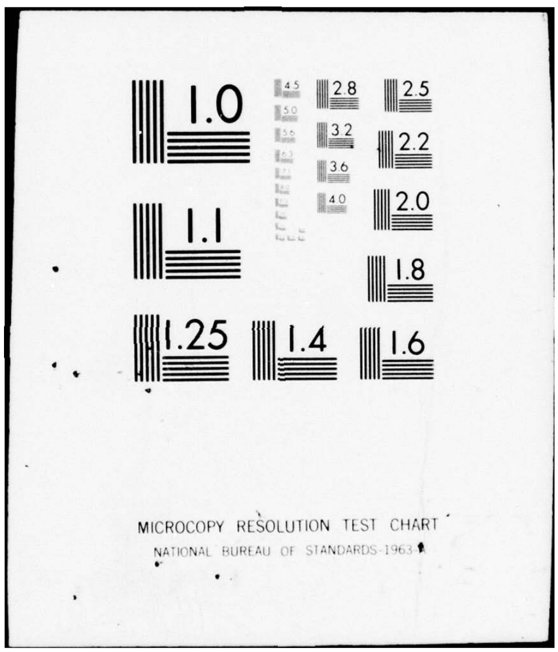
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A GUIDE TO USE OF THE XWAVE PROGRAM: PART I — RADIATED PRESSURES FROM VIBRATING STRUCTURES

by

Francis M. Henderson

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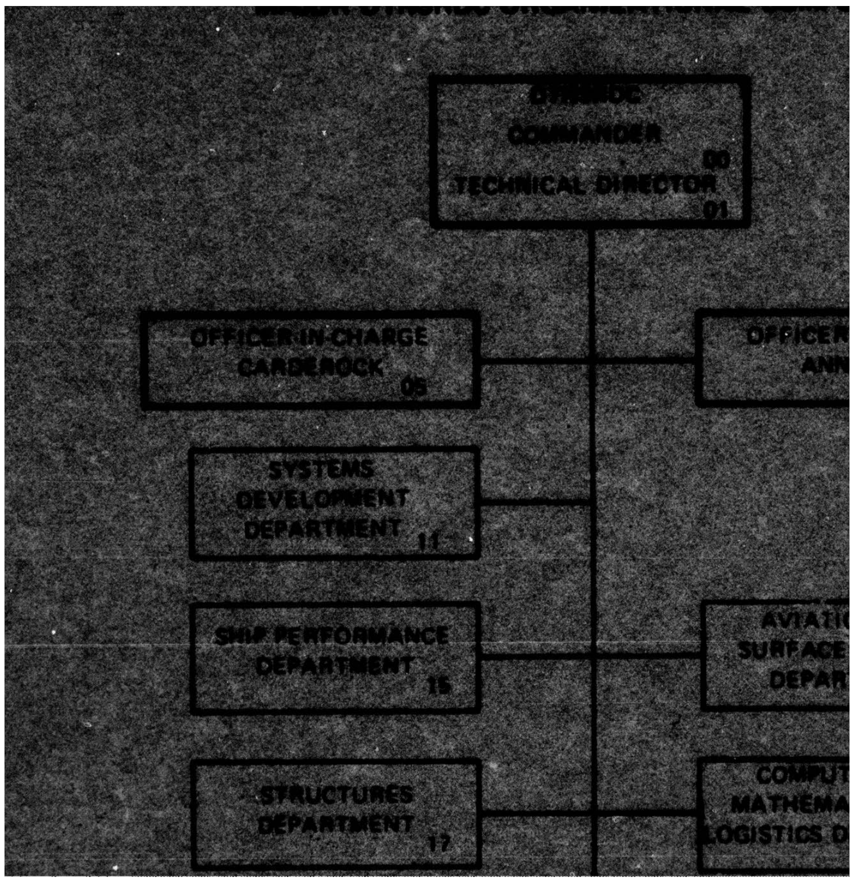
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

XWAVE is a computer program for calculating the steady-state pressures in an infinite fluid exterior to a closed, arbitrary shaped structural surface for which a normal velocity distribution has been determined. ~~For this report~~ the velocity distribution is considered to result from a vibrational motion of the surface. The method of the program is based on a

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numerical solution of the surface Helmholtz integral equation which relates surface pressure to velocity and a subsequent numerical integration of the Helmholtz exterior field equation which relates field pressures to the surface velocity and pressure distribution.

The program offers a variety of capabilities including; automatic generation of surface acoustic models for certain surfaces of revolution; automatic generation of several types of velocity boundary condition; an option for incorporating structure-fluid interaction effects through use of surface mobility data; and ~~the~~ use of input data to dynamically allocate computer core storage for arrays.

Three calculations illustrate XWAVE data configurations and ~~as well as~~ some applications of the program to problems involving vibrating structural surfaces.

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ABSTRACT

XWAVE is a computer program for calculating the steady-state pressures in an infinite fluid exterior to a closed, arbitrary shaped structural surface for which a normal velocity distribution has been determined. For this report the velocity distribution is considered to result from a vibrational motion of the surface. The method of the program is based on a numerical solution of the surface Helmholtz integral equation which relates surface pressure to velocity and a subsequent numerical integration of the Helmholtz exterior field equation which relates field pressures to the surface velocity and pressure distribution.

The program offers a variety of capabilities including automatic generation of surface acoustic models for certain surfaces of revolution, automatic generation of several types of velocity boundary condition, an option for incorporating structure-fluid interaction effects through use of surface mobility data, and the use of input data to dynamically allocate computer core storage for arrays.

Three calculations illustrate XWAVE data configurations as well as some applications of the program to problems involving vibrating structural surfaces.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

This report documents the use of XWAVE, a digital computer program for computing the radiated sound pressure from the surface of a vibrating structure submerged in an infinite fluid. The particular problem considered is that of a structure with arbitrary closed surface S whose points s vibrate with time-harmonic motion as indicated in Figure 1.

The pressure in the surrounding fluid then also varies harmonically and the wave equation will have the form

$$\nabla^2 p + k^2 p = 0 \tag{1}$$

where p = sound pressure in the fluid (pressure above ambient)

k = wave number of vibration; $k = \omega/c$

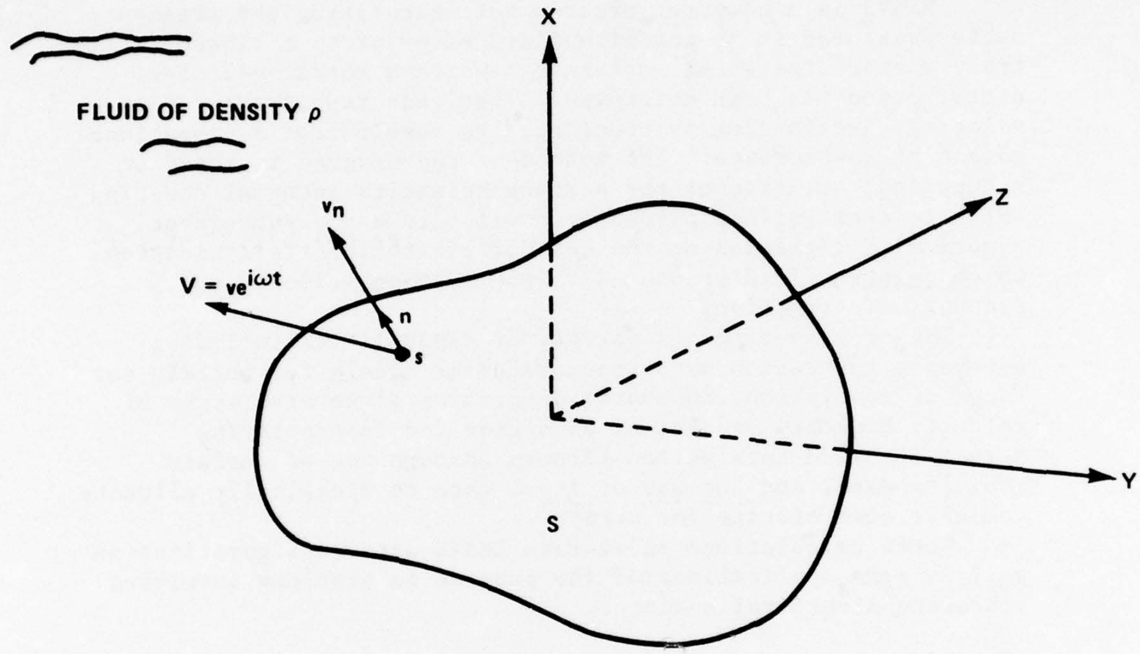

Figure 1 - Vibrating Structure Immersed in an Infinite Fluid

ω = angular frequency of vibration

c = speed of sound in the fluid

The factor $e^{i\omega t}$ is divided out.

The boundary condition on the structural surface contacting the fluid is

$$\frac{\partial p(s)}{\partial n} = - i\omega\rho \, v_n(s) \qquad (2)$$

where, referring to Figure 1,

s = point on the closed surface S of arbitrary shape

n = direction normal to the structural surface at s

v_n = normal component of velocity magnitude v at s

ρ = fluid density

The boundary condition at infinity is

$$p(\underline{z}) \approx \frac{e^{ik|\underline{z}|}}{|\underline{z}|} \; ; \; |\underline{z}| \rightarrow \infty \tag{3}$$

where $\underline{z}$ denotes a point in the fluid.

XWAVE achieves its solution to this boundary value problem by first calculating the numerical solution to a surface Helmholtz integral equation formulation that relates the unknown surface pressure distribution to a normal surface velocity distribution which is specified. The field pressures are solved by simple quadrature of an integral formulation that relates the field pressures to the surface pressure and normal velocity.

The integral formulations and associated numerical solution techniques which the program uses have already been discussed.[1*] Various practical applications of the program have also been reported.[2-4**]

The purpose here is to briefly review the integral equations and their forms for numerical solution, to summarize the types of data required by XWAVE, and to illustrate how the data are assembled for running applications.

---

[1] Chertock, G., "Integral Equation Methods in Sound Radiation and Scattering from Arbitrary Surfaces," NSRDC Report 3538 (Jun 1971).

[2] Henderson, F.M., "Radiation Impedance Calculations with the XWAVE Computer Program," NSRDC Report 4033 (Mar 1973).

[3] Henderson, F.M., "Numerical Computation of the Sound Pressure on a Spheroidal Surface Resulting from a Zone Vibrating near a Critical Frequency," NSRDC Report 4213 (Nov 1973).

[4] Henderson, F.M., "A Structure-Fluid Interaction Capability for the NASA Structural Analysis (NASTRAN) Computer Program," NSRDC Report 3962 (Aug 1972).

[*] Reported informally by F.M. Henderson in NSRDC Technical Note CMD-24-71 (Computation of the Sound Pressure Field about Submerged Vibrating Structures by a Method of G. Chertock) in August 1971.

[**] Reported informally by F.M. Henderson in NSRDC Technical Note CMD-41-71 (Calculation of the Induced Mass of Finite Cylinders in an Infinite Fluid) in November 1971.

OVERVIEW OF EQUATION FORMULATIONS FOR SURFACE AND FIELD PRESSURE

The heart of the XWAVE calculation is the numerical solution of the Helmholtz equation for surface pressure:

$$\frac{p(\underline{y}')}{2} - \iint_S p(\underline{y}) \frac{\partial}{\partial n}\left[\frac{e^{ik|\underline{y}'-\underline{y}|}}{4\pi|\underline{y}'-\underline{y}|}\right] dS = \iint_S \frac{\partial p(\underline{y})}{\partial n} \frac{e^{ik|\underline{y}'-\underline{y}|}}{4\pi|\underline{y}'-\underline{y}|} dS \qquad (4)$$

where $\underline{y}$ and $\underline{y}'$ denote surface points.

The program uses a form of this equation in which both sides have been divided by $\rho c v_0$ with v_0 a reference velocity for the vibration mode of the surface and in which the following substitutions have been made:

Dimensionless surface pressure $\bar{p}(\underline{y}) = p(\underline{y})/\rho c v_0$

Dimensionless surface normal velocity $\bar{v}(\underline{y}) = v(\underline{y})/v_0$

Boundary condition from Equation (2)

$$\frac{\bar{p}}{2}(\underline{y}') - \iint_S \bar{p}(\underline{y}) \frac{\partial}{\partial n}\left[\frac{e^{ik|\underline{y}'-\underline{y}|}}{4\pi|\underline{y}'-\underline{y}|}\right] dS = -ik \iint_S \bar{v}_n(\underline{y}) \frac{e^{ik|\underline{y}'-\underline{y}|}}{4\pi|\underline{y}'-\underline{y}|} dS \qquad (5)$$

The numerical method of solving Equation (5) is based on a subdivision of the structural surface S into N interconnecting patches of area or stations as indicated in Figure 2. The kernel functions of Equation (5)

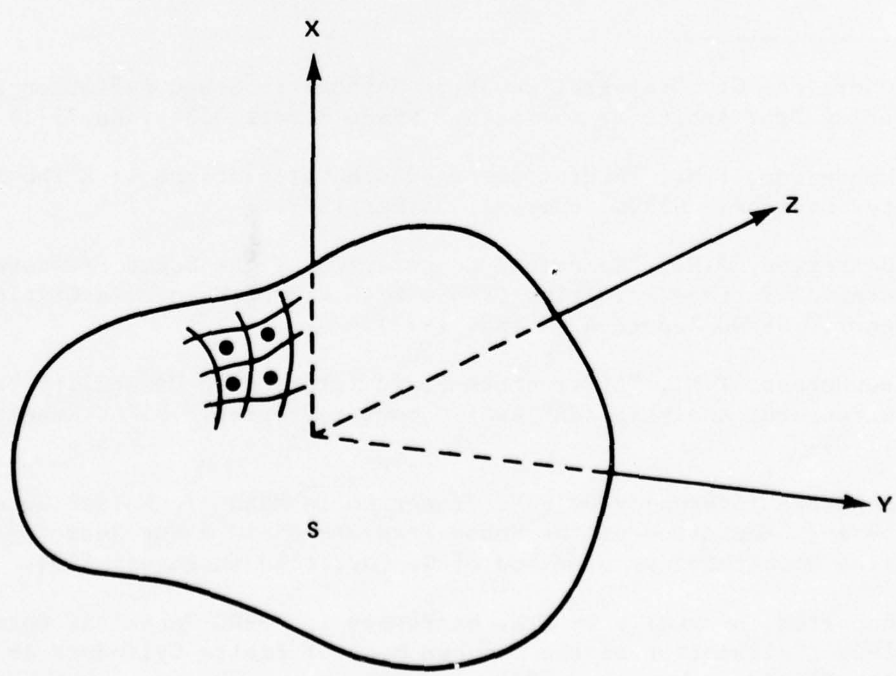

Figure 2 - Structural Surface Subdivided into Stations

can then be evaluated for each station paired, in turn, with all stations including itself to yield coefficients of a system of linear equations for the pressure at each station. Since details of the evaluation are already available (see Reference 1 and the single asterisk footnote on page 3), it is sufficient for present purposes simply to recall the form of the equations (see Equation (15) from CMD-24-71):

$$\left([G2_{ij}][A_{jj}] - \frac{1}{2}[I]\right)\{\bar{p}_j\} = ik\,[G_{ij}][A_{jj}]\{\bar{v}_j\},\ i,\ j = 1,\ 2,\ \ldots,\ N \qquad (6)$$

where $[G_{ij}]$, $[G2_{ij}]$ = matrices whose elements are the evaluated kernel functions for stations i,j

$[I]$ = identity matrix

$[A_{jj}]$ = diagonal matrix whose elements are the station areas

$\{\bar{p}_j\}$ = vector of nondimensional pressures; $\bar{p}_j = p_j/\rho c v_0$ with v_0 a reference velocity for the vibration mode

$\{\bar{v}_j\}$ = vector of surface normal in-fluid velocities nondimensionalized; $\bar{v}_j = v_j/v_0$

i,j refer to station numbers

N = number of surface stations

The structure-fluid interaction effect can be incorporated directly into Equation (6) through the modification (see Equation (B5) in CMD-24-71):

$$\left([G2_{ij}][A_{jj}] - \frac{1}{2}[I] + i\omega\rho[G_{ij}][A_{jj}][q_{ij}][A_{jj}]\right)\{\bar{p}_j\} = ik[G_{ij}][A_{jj}]\{\bar{u}_j\};\ i,j = 1,\ 2,\ \ldots,\ N \qquad (7)$$

where q_{ij} is the in-vacuo normal surface velocity response at Station i due to a unit force of frequency ω acting normal to the surface at Station j, and $\{\bar{u}_j\}$ is a vector of the in-vacuo normal surface velocity for the vibration mode.

When the wave number k is not at or near one of the set of internal resonant wave numbers of the cavity enclosed by the structural surface, a solution for surface pressure can be obtained from Equation (6). Otherwise, some special computing procedure must be used.[1,3] A similar condition applies for Equation (7) although in this case the set of critical frequencies may differ from those of Equation (6).

The surface pressure solution together with the normal surface velocities permit field pressures to be calculated from the integral formulation

$$\bar{p}(\underline{z}) = - ik \iint_S \bar{v}(\underline{y}) \frac{e^{ik|\underline{z}-\underline{y}|}}{4\pi|\underline{z}-\underline{y}|} dS + \iint_S \bar{p}(\underline{y}) \frac{\partial}{\partial n} \left[\frac{e^{ik|\underline{z}-\underline{y}|}}{4\pi|\underline{z}-\underline{y}|}\right] dS \qquad (8)$$

For near or intermediate field pressures, the matrix equation which can be used to approximate Equation (8) by using the subdivided surface S (Figure 2) is (see Equation (20) of CMD-24-71):

$$\{\bar{p}(\underline{z}_i)\} = - ik[\tilde{G}_{ij}][A_{jj}]\{\bar{v}(\underline{y}_j)\} + [\tilde{G}2_{ij}][A_{jj}]\{\bar{p}(\underline{y}_j)\}, \quad \begin{array}{l} i = 1, 2, \ldots, M \\ j = 1, 2, \ldots, N \end{array} \qquad (9)$$

where M = number of field points selected

N = number of surface stations

z_i = location of field point

y_j = surface station location

$[\tilde{G}_{ij}]$ = matrix whose elements are generated by evaluating the function $(e^{ik|\underline{z}-\underline{y}|})/(4\pi|\underline{z}-\underline{y}|)$ for each field point $\underline{z}_i$ paired in turn with all surface stations $\underline{y}_i$.

$[\tilde{G}2_{ij}]$ = matrix whose elements are generated by evaluating the function $\frac{\partial}{\partial n}\left[(e^{ik|\underline{z}-\underline{y}|})/(4\pi|\underline{z}-\underline{y}|)\right]$ for each field point paired, in turn, with all surface stations.

A more simplified form of Equation (8) can be derived for the pressure calculation at the far-field points; see CMD-24-71. With reference to the

notation in Figure 3, the form is recalled to be (see Equation (13) of CMD-24-71)

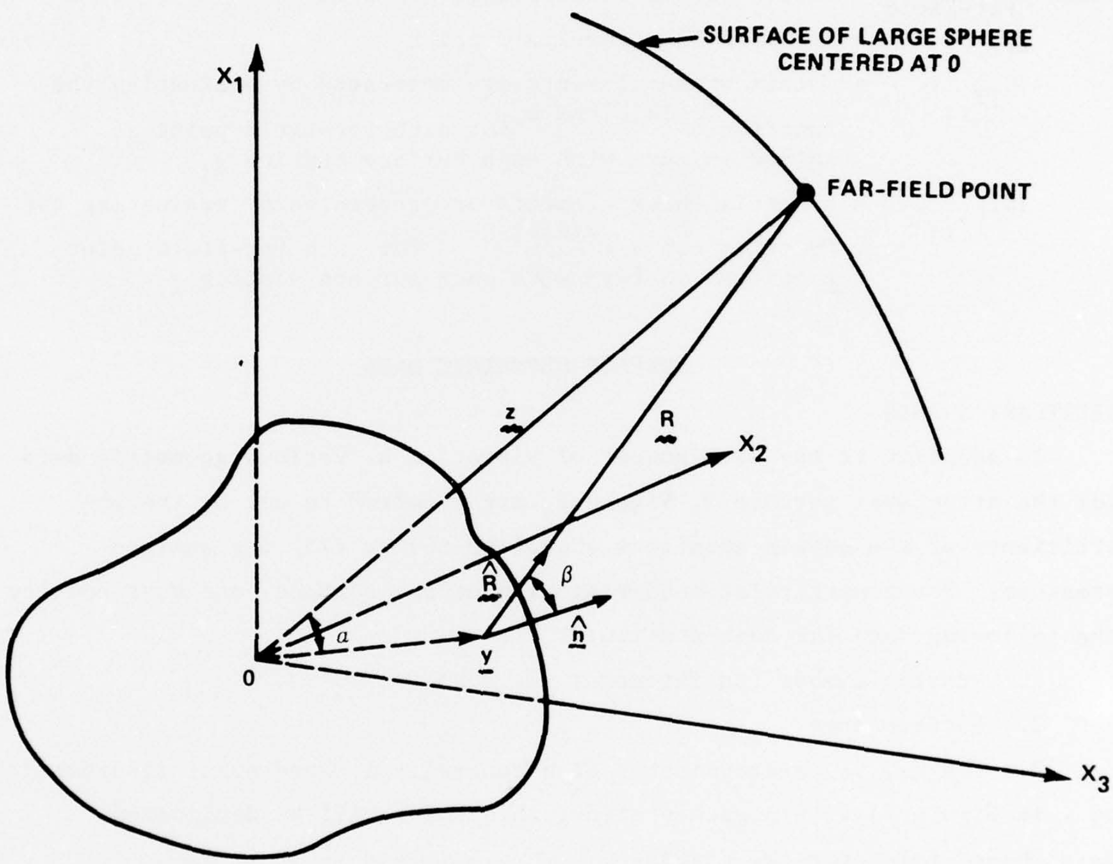

Figure 3 - Geometry for Far-Field Pressure Calculation

$$F(\underset{\sim}{z}) = \iint_S [\bar{v}(\underset{\sim}{y}) + \bar{p}(\underset{\sim}{y}) \cos \beta] e^{-ik|\underset{\sim}{y}|\cos \alpha} \, dS \tag{10}$$

where

$$F(\underset{\sim}{z}) \equiv \frac{i}{k} \bar{p}(\underset{\sim}{z}) \frac{4\pi |\underset{\sim}{z}|}{e^{ik|\underset{\sim}{z}|}}$$

The matrix equation which approximates Equation (10) for the subdivided surface S is (see Equation (23) of CMD-24-71):

$$\{F(\underset{\sim}{z}_i)\} = [G_{FF_{ij}}][A_{jj}]\{\bar{v}(\underset{-}{y}_j)\} + [G2_{FF_{ij}}][A_{jj}]\{\bar{p}(\underset{-}{y}_j)\}, \quad \begin{array}{l} i = 1, 2, \ldots, M_{Far-Field} \\ j = 1, 2, \ldots, N \end{array} \tag{11}$$

where $M_{Far-Field}$ = number of far-field points selected

$\underset{\sim}{z}_i$ = location of a far-field point

$[G_{FF_{ij}}]$ = matrix whose elements are generated by evaluating the function $e^{-ik|\underset{-}{y}|\cos\alpha}$ for each far-field point $\underset{\sim}{z}_i$ paired in turn with each surface station $\underset{-}{y}_i$

$[G2_{FF_{ij}}]$ = a matrix whose elements are generated by evaluating the function $\cos\beta\, e^{-ik|\underset{-}{y}|\cos\alpha}$ for each far-field point $\underset{\sim}{z}_i$ paired in turn with each surface station $\underset{-}{y}_i$.

SURFACE GEOMETRIC DATA

ARBITRARY SHAPES

In addition to the wave number of vibration k, various geometric data for the structural surface S, Figure 2, are required to set up the coefficients of the matrix equations (Equation (6) or (7)) for surface pressure. For a particular subdivisioning of the surface, one must specify the following data for each station:

1. Station number (an integer $1 \leq \ell \leq N$)
2. Surface area
3. The x-, y-, z-coordinates of a centrally located point (indicated by . in Figure 2) within each station; this point will be designated as a "base" point for the station
4. The x-, y-, z-coordinates of unit normal vector to the surface at the base point
5. Local curvature of the surface with reference to the base point

If the fluid-surface interaction effect is to be calculated by using Equation (7), the above data are extended to include the sound speed in the fluid c, the fluid mass density ρ, and the elements q_{ij} of the surface dynamic mobility matrix (see page 5). The q_{ij} are assumed here to be available from a source external to XWAVE and may derive from

an analytic, numerical, or experimental analysis of surface mobility. The program requires only that these data be compatible with the particular surface modeling being used and that they are in the proper format as described in the section entitled DATA FORMATS.

XWAVE incorporates several options for supplying the data indicated in Items 2-5 to the subroutines which calculate matrix coefficients. One option, the default option, is used with those surfaces for which automatic generation of the above data has not yet been included in the program. For such cases the entire geometric data for the surface model are specified on punched cards to be read into storage by the program.

The remaining options for surface geometric data pertain to certain surfaces of revolution which have been used in testing and applying the program.

SURFACES OF REVOLUTION

XWAVE presently has the capability for automatically generating the surface geometric data for three types of revolved surface. We shall consider in detail the data specified to the program for each surface.

Piecewise Conical Shell

These are defined as surfaces formed by revolving curves consisting of straight line segments joined end to end. Examples of this kind of surface are shown in Figure 4.

The primary portion of surface utilized in generating the geometric data is defined here to be a "region." A region is formed by revolving either the full or partial length of a straight line from the generating curve through a specified arc. The data required to specify the extent of a region to the program are indicated in Figure 5. In the figure, z_1, z_2 indicate the extent of the region along the z-axis, r_1, r_2 determine the line segment slope, and θ_1, θ_2 indicate the extent of the region in θ, θ_1 and θ_2 being measured from the positive y-axis counterclockwise.

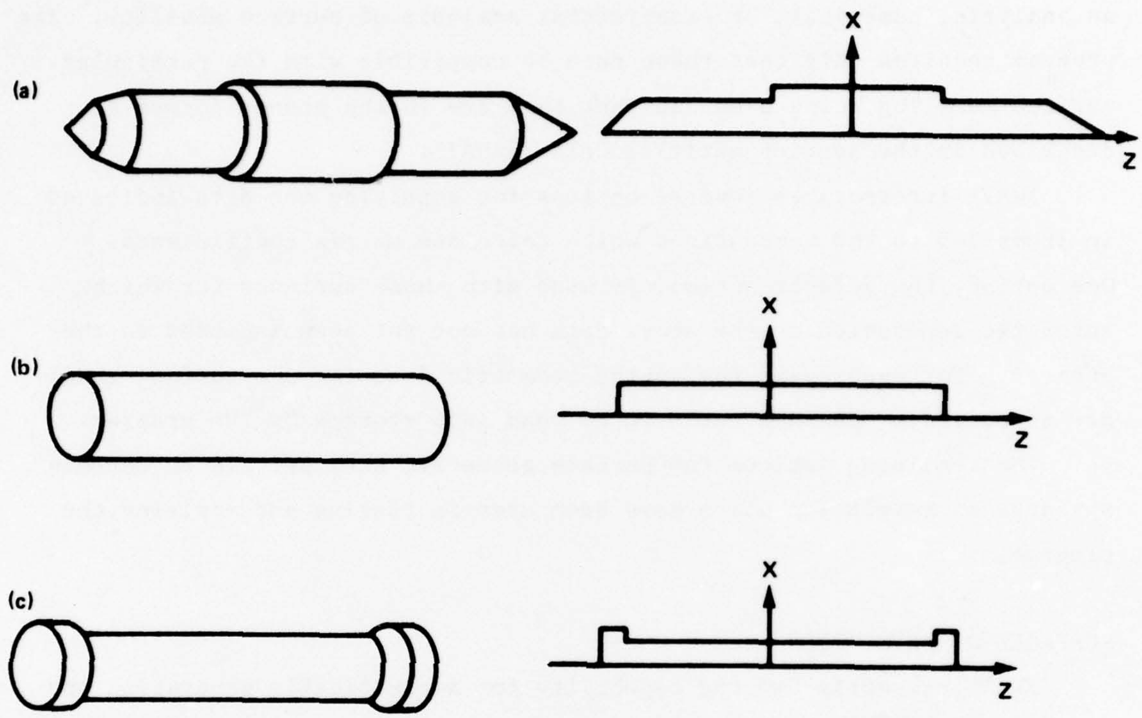

Figure 4 - Surfaces Generated by Revolving Curves Formed from Straight Line Segments

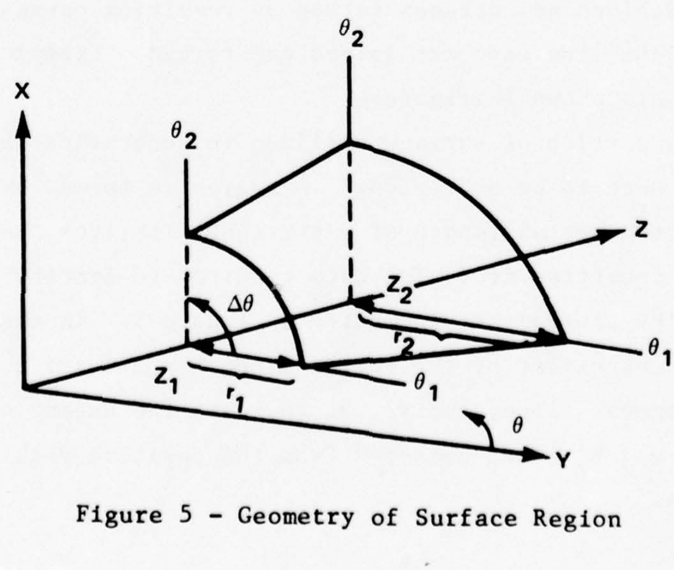

Figure 5 - Geometry of Surface Region

Figure 6 illustrates some typical surface regions which can be formed. The disk represents the case

$$\begin{cases} z_1 = z_2 \\ r_1 = 0,\ r_2 > 0 \\ \theta_1 = 0 \text{ degrees},\ \theta_2 = 360 \text{ degrees} \end{cases}$$

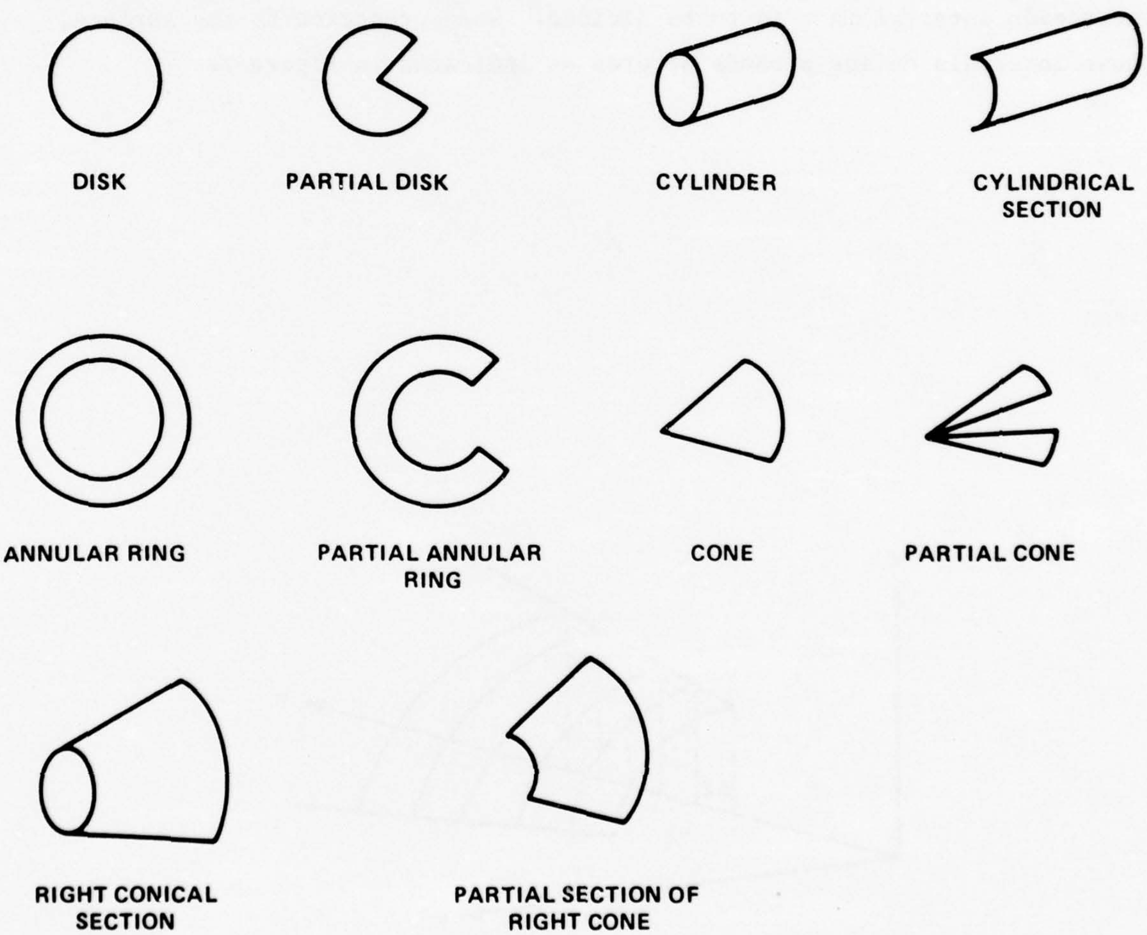

Figure 6 - Typical Surface Regions from Revolving Straight Line Segments

and the annular ring represents the case

$$\begin{cases} z_1 = z_2 \\ r_1 > 0,\ r_2 > r_1 \\ \theta_1 = 0 \text{ degrees},\ \theta_2 = 360 \text{ degrees} \end{cases}$$

The subdivisioning of the surface within a region into stations is controlled by two integers n and m supplied as data. The first integer designates the number of equal increments ($\Delta z = (z_2 - z_1)/n$) into which the region interval in z is to be divided. When projected to the surface, these intervals define n bands of area as indicated in Figure 7.

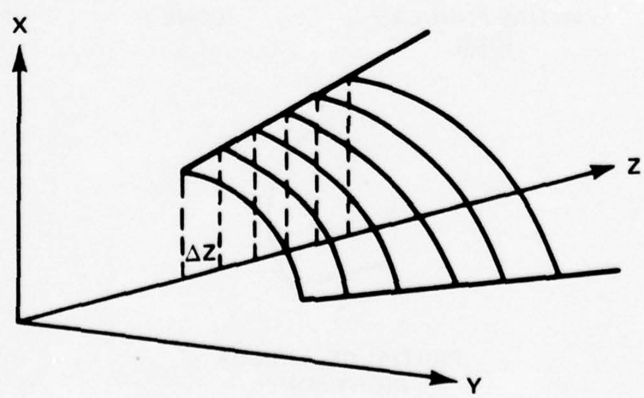

Figure 7 - Surface Region Subdivided into Bands of Area

The second integer m designates the number of equal increments into which the θ interval of the region is to be divided; $\Delta\theta = (\theta_2 - \theta_1)/m$. The pair n,m then controls the station modeling of the region as shown in Figure 8.

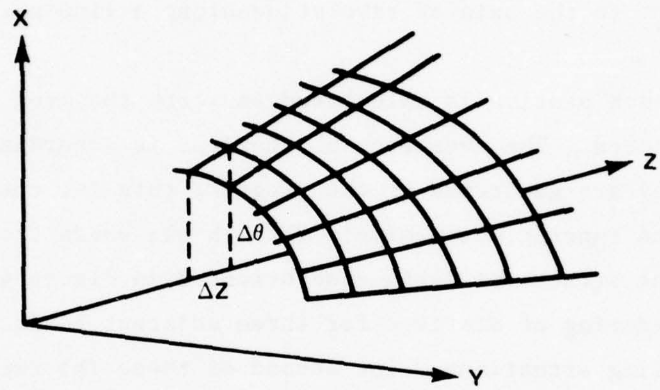

Figure 8 - Surface Region Subdivided into Stations

The XWAVE data generator automatically locates a "base" point within each station area at a position 1/2 ΔZ, 1/2 $\Delta\theta$. Coordinates of a unit normal and the mean surface curvature are calculated for the "base" point by using formulas previously discussed (see single asterisk footnote on page 3). If the generating line for the region is perpendicular to z, the coordinates of the unit normals to base points within are simply x=0, y=0, z= ± 1. The sign of z is resolved by specifying it as an item of data accompanying the limits on extent of the region (page 9) and m and n. The sign is easily resolved for all other regions from the slope of the generating line.

The surface curvature used at each station is taken to be the mean curvature at the base point. The mean curvature is defined as one-half the sum of the maximum and minimum principal normal curvatures at the base point. For surfaces of revolution, these principal lines of curvature are the meridian and parallel passing through the base point.

Note from Figure 6 that the surface regions under consideration are either flat or have curvature only in the direction of the parallels. In the first instance, the curvature is obviously zero for all stations within the region. In the second instance, curvature at the base point is the curvature of the local parallel which is given by the distance from the base point to the axis of revolution along a line perpendicular tc the surface.

The area of each station is calculated as 1/mth the area of the band in which it is located. The numbering of stations is according to the order in which they are generated by the program; this is, counterclockwise about each band and running successively through all bands from the left to right end of the structural surface as oriented in Figure 4. Figure 9 illustrates the ordering of stations for three adjacent bands of area in two possible modeling situations. The second of these (b) represents the case where a surface region 360 degrees in extent (for example a

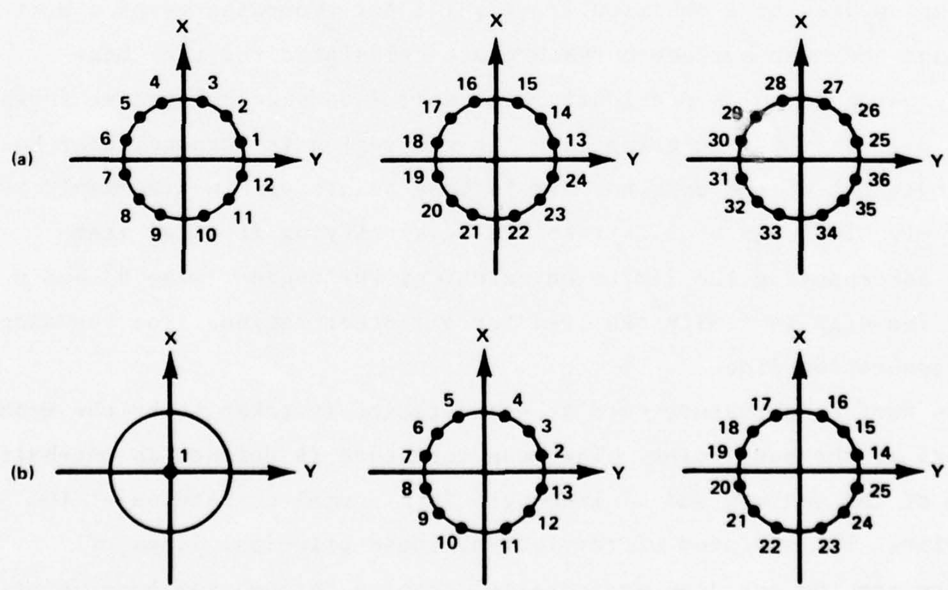

Figure 9 - Ordering of Surface Station Numbers for Bodies of Revolution

disk or cone as in Figure 6) and containing a single station is used in closing off the end of a structural surface. The dots in Figure 9 designate station base points. As indicated, the reference station for beginning the numbering in each band (except end bands with one station) is the first station generated above the positive y-axis.

Prolate Spheroid

Here surfaces are formed by revolving ellipses with major axis along the axis of revolution. The surface profile is specified to the data generator through two input parameters AA and BB; these are respectively the major and minor axes of the generating ellipse which is assumed to be centered about the origin of the coordinates.

Figure 10 shows a typical region on this surface.

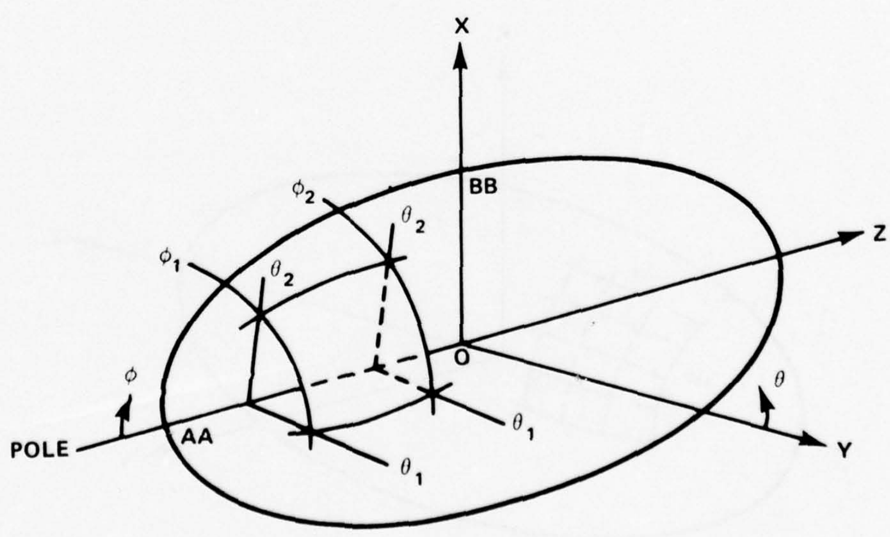

Figure 10 - Typical Region of a Prolate Spheroidal Surface

To specify a prolate spheroidal region, the following data are supplied to the data generator:

1. θ_1, θ_2 the angular extent of the region with respect to the generating axis z; θ is measured counterclockwise from the positive y-axis; 0 degrees $\leq \theta \leq$ 360 degrees

2. ϕ_1, ϕ_2 the angular extent of the region in colatitute measured from the z-negative pole of the body; 0 degrees $\leq \phi \leq$ 180 degrees

Modeling of the surface region is determined by integer data n and m for the region. The first integer specifies the subdivisioning of the region into n equal bands of latitude ($\Delta\phi = (\phi_2-\phi_1)/n$ degrees); the second integer specifies m equal strips of longitude ($\Delta\theta = (\theta_2-\theta_1)/m$ degrees), as indicated in Figure 11.

The area of each station within a band of latitude $\Delta\phi$ is 1/mth total area of the band. The base point within each band is located at 1/2 $\Delta\theta$, 1/2 $\Delta\phi$.

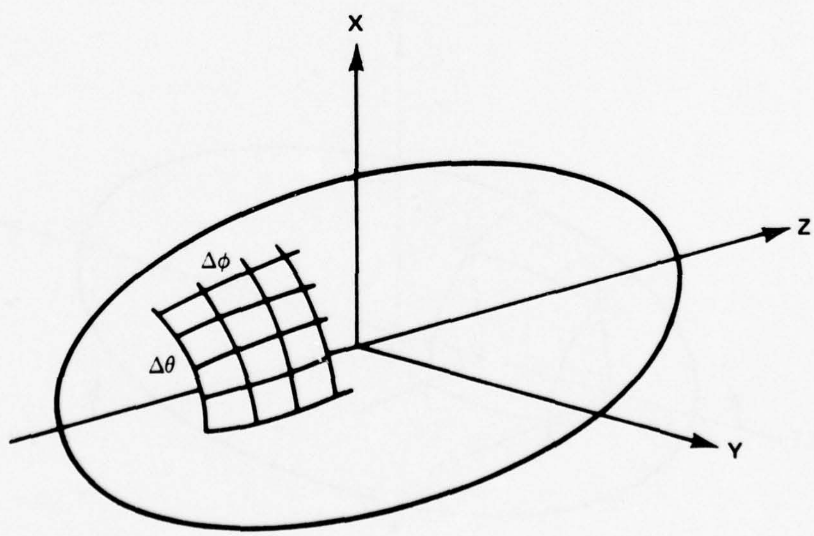

Figure 11 - Surface Modeling of Prolate Spheroidal Region

A mean curvature for each station is found, as in the case of conical shell regions, from the curvatures of the meridian and parallel through the base point; the former curvature is readily determined from the equation for the particular ellipse in the xz-plane.

The implied numbering of stations generated follows the pattern illustrated in Figure 9; single end stations as indicated in part (b) of the sketch now become spheroidal caps.

Sphere

The particular spherical profile is specified to the data generator through a single input parameter RADIUS. The data to specify surface regions and their subdivision into stations are the same as just described for the prolate spheroid.

SYMMETRY

It can easily be shown that when symmetry planes occur simultaneously for both the surface geometry and velocity boundary conditions, they are also symmetry planes for the surface pressure solution. In other words, if the surface has a symmetry plane which is also a symmetry or antisymmetry plane for the boundary condition, then the plane is respectively a symmetry or antisymmetry plane for the pressure solution. This result enables one to specify some basic portion of the total surface for modeling and to obtain the modeling of the remainder of the surface through reflections of the basic model through symmetry planes.

XWAVE incorporates options for using the principal coordinate planes as symmetry planes in specifying the structural surface model. The elements or stations which model the nonredundant portion of the surface with respect to these symmetry planes are referred to as "basic" elements. The elements which model the remainder of the surface are obtained by reflecting the basic elements in the symmetry planes. Figure 12 illustrates a basic surface element and the images of successive reflections (numbered) in the coordinate planes (denoted by subscripts).

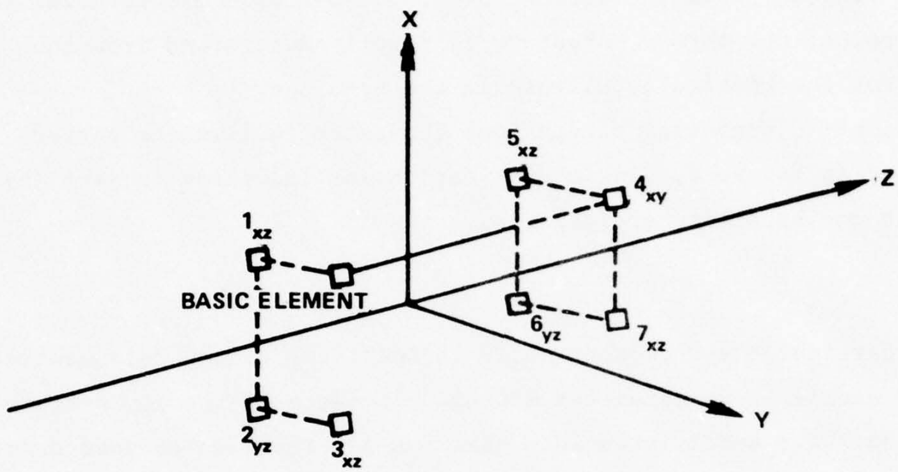

Figure 12 - Basic Surface Element Reflected in Symmetry Planes

The total of basic plus reflected elements gives the "effective" number of elements for the surface model. The total computer core storage required for the surface geometric data is, however, only that required for the basic elements since the data for reflected elements can be obtained from the basic element data by appropriate sign changes.

With regard to generation of the coefficient matrix (for example, Equation (6)) for surface pressure, the program recognizes principal coordinate plane and axial symmetry. In the case of principal coordinate plane symmetry alone, the order of the matrix equation is equal to the number of basic elements or stations used to model the nonredundant portion of the structural surface. The ijth coefficient of the matrix is composed of a sum of terms, the first of which represents an evaluation of the kernel function for the pairing of basic element i and basic element j. The remaining terms of the sum, respectively, represent an evaluation of the kernel for pairings of the same basic element i with all reflected images of the same basic element j in the symmetry planes. The sign of a term is plus if the image element is from reflection across a symmetry plane of the boundary condition; the sign is minus if across a plane of antisymmetry.

When the surface geometry and boundary conditions are axially symmetric, the pressure solution need be obtained for only one station in each latitude band. We arbitrarily select these stations on the x-positive side of the yz-plane and bordering $\theta = 0$ degrees (see Figure 8).

The matrix coefficients are generated by a modification of the procedure described above for principal coordinate plane symmetry. In the first part of the calculation, the index i is constrained to reference just the single selected station in each band of latitude and the kernel function is evaluated for all station pairs i,j; reflected images of j in the coordinate planes are accounted for as before. In the second and last stage, those terms resulting from the pairing of station i with circumferential stations j within individual bands are added together. This addition accounts for the fact that the circumferential stations j (where $j \neq i$) are actually images of the base station $j = i$, when it is successively reflected in symmetry planes inclined at appropriate angles to the coordinate planes. The matrix of coefficients generated in this way is seen to be of order equal to the total number of latitude bands prescribed for the surface model.

The procedures described for generating the coefficient matrix for cases involving symmetry apply equally, of course, to the generation of elements of the matrix product $[G_{ij}][A_{jj}]$ in the surface pressure equation.

BOUNDARY CONDITION DATA

The boundary condition data which must be supplied to the XWAVE program consist of the elements of the vector $\{\bar{v}_j\}$ (see Equation (6)) or the vector $\{\bar{u}_j\}$ (see Equation (7)). For the latter case in which structure-fluid interaction effects are being incorporated into the calculation, the vector $\{\bar{u}_j\}$ is assumed to be generated external to XWAVE, most likely by a program for dynamic structural analysis. The elements of $\{\bar{u}_j\}$ are assumed to be stored, along with the mobility matrix elements $[q_{ij}]$, on an auxiliary storage device (disk) or in card form for reading by XWAVE.

XWAVE incorporates several options for specifying the in-fluid velocity vector $\{\bar{v}_j\}$. One option allows the user to specify a single value of velocity $\bar{v}$ to be applied at each station within a region on a surface of revolution (see Figure 8). Assignment of $\bar{v}$ to each station is handled automatically by the program. In the case of axial symmetry, $\bar{v}$ is assigned to only one station in each band of latitude within the region (refer to page 19, top).

A second option, also designed for use with surfaces of revolution, automatically generates a normal velocity distribution from the expression[5]

$$\bar{v}_n = v_0 \psi(z) \cos M\theta \tag{12}$$

where v_0 = constant velocity amplitude

$\psi(z)$ = arbitrary dimensionless function of z

M = integer constant

A variety of assumed velocity distributions corresponding to vibration modes of surfaces of revolution can be obtained from the above expression. For example, longitudinal modes and circumferentially symmetric modes with $M = 0$, flexural modes with $M = 1$, and lobar modes with $M > 1$.[5] Additional distributions can be obtained from linear combinations of these modes.

The data supplied to XWAVE with this option are the constants v_0 and M and for each surface region the values $\psi(z_i)$, $i = 1, 2, 3, \ldots, LB$; LB denotes the number of latitude bands into which the region is subdivided. The points z_i coincide with the z-coordinates of the base point locations (i.e., $1/2\ \Delta z$; see Figure 8) within each band. Similarly, the particular values of θ, θ_i used in computing $\bar{v}_n$ correspond to the angular locations ($1/2\ \Delta\theta$) of base points within each band.

A third option allows the user to explicitly specify the normal velocity to be assigned each station in the surface model. This option provides for cases where the facilities of the first and second option do not apply. The velocity data with this option are read into the computer from punched cards.

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[5] Chertock, G., "Sound Radiation from Vibrating Surfaces," Journal of the Acoustical Society of America, Vol. 36, No. 7, pp. 1305-1313 (Jul 1964).

DATA FOR ITERATIVE SOLUTION OF THE SURFACE PRESSURE EQUATION

If in Equation (6) we denote

$$\left([G2_{ij}][A_{jj}] - \frac{1}{2}[I]\right) \equiv [M_{ij}]$$

and

$$ik[G_{ij}][A_{jj}] \equiv [B_{ij}]$$

the equation can be written

$$[M_{ij}]\ \{\bar{p}_j\} = [B_{ij}]\ \{\bar{v}_j\} = \{F_i\} \qquad (13)$$

A similar expression can be written for Equation (7). XWAVE uses a Guass-Seidel iteration scheme for solving Equation (13). The form of the iteration is

$$\bar{p}_i^{(n+1)} = \bar{p}_i^{(n)} + H \cdot \frac{1}{M_{ii}} \left[F_i - \sum_{j=1}^{i-1} M_{ij}\ \bar{p}_j^{(n+1)} - \sum_{j=1}^{N} M_{ij}\ \bar{p}_j^{(n)}\right] \qquad (14)$$

with H the relaxation factor.

The initial value of $\bar{p}_i$ is given by

$$\bar{p}_i^{(0)} = \frac{F_i}{M_{ii}} \qquad (15)$$

The iteration is terminated either when

$$|\bar{p}_i^{n+1} - \bar{p}_i^{n}|_{max} \leq \varepsilon \qquad (16)$$

or when a prespecified bound on the number of iterations is reached. If the upper bound on iterations is met first, the last vector computed is printed out. In this case the magnitude $|\bar{p}_i^{n+1} - \bar{p}_i^{n}|_{max}$ which is printed after each iteration can be used to estimate the degree to which the the pressure vector has converged.

Data input for the iterative solution will include the relaxation factor H, the convergence criterion ϵ, and an upper bound on the number of iterations.

FIELD POINT DATA

XWAVE incorporates an option for either direct specification or automatic generation of field point locations z_i (see page 6) and $\underset{\sim}{z}_i$ (see page 8). As noted earlier, far-field points $\underset{\sim}{z}_i$ are assumed to lie on a sphere of large radius centered on the submerged structure. Near and intermediate points $\underset{\sim}{z}_i$ lie between the structural surface and those distances which, in an acoustic sense, can be considered to be far field.

To directly specify far-field points, one supplies on punched cards the longitude and latitude of each point desired according to the format given in the section entitled DATA FORMATS. The coordinate system used in referencing longitude ϕ and colatitude ψ is shown in Figure 13.

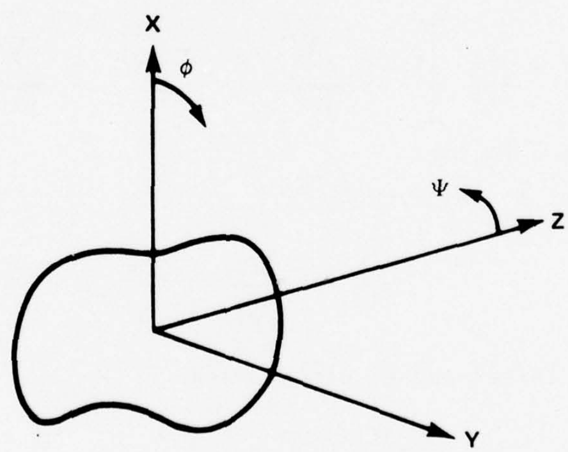

Figure 13 - Spherical Surface Coordinate System Centered in a Structure

Alternatively, one can select an option to automatically generate points (ψ,θ) on the spherical surface at infinity. When this option is used, the data specified include:

1. The limiting number of degrees of colatitude extending from $\psi = 0$ degrees (0 degrees $\leq \psi \leq$ 180 degrees)

2. The limiting number of degrees of longitude extending from $\phi = 0$ degrees (0 degrees $\leq \phi \leq$ 360 degrees)

3. The number of colatitudes desired

4. The number of longitudes desired with each colatitude other than 0 or 180 degrees

An arbitrary distribution of near or intermediate field points is obtained by specifying the x-, y-, z-coordinates of each point. For automatic generation of field points on a spherical surface, one specifies in place of Items 1 and 2 above, the colatitude limits ψ_1, ψ_2, the longitude limits ϕ_1, ϕ_2, the data of Items 3 and 4, and radius R of the sphere.

DATA FOR DYNAMIC CORE ALLOCATION

The remaining data required for XWAVE specify the sizes of certain arrays used by the program. These data have two purposes: (1) to enable the size of arrays which primarily store input data (such as the surface geometric data, field points, boundary conditions, etc.) to be tailored to meet just the requirements of the particular application and (2) to allow the user to decide how much core is to be committed for matrix manipulations, or in other words, to what degree the matrix manipulations will be handled as in-core or out-of-core operations. The flexibility offered in transforming from essentially in-core to out-of-core considerably increases the size of a job (i.e., with respect to number of surface elements) that can be treated. The ability to reduce internal core requirements also offers the user an advantage for applications involving relatively small running times; by virtue of the reduced core, he can select a higher running priority and better throughput time. The economics of running the program are also enhanced by the core adjustment feature.

XWAVE arrays, that is, those of significant length, are controlled through the use of 14 dimensions. The rules for assigning values to these dimensions are tabulated below.

Dimension	Value	Application Condition
D1	Total number of surface elements in the surface model.	Velocity boundary condition has no principal coordinate plane symmetries. Structural surface geometry has no principal coordinate plane symmetries.
	Total number of surface elements used to model the portion of structural surface which is nonredundant with respect to principal coordinate planes of symmetry. Note: For surfaces of revolution modeled by using the automatic input facility, this dimension is equal to the total sum of n x m (see pages 12,13) over all surface regions.	Structural surface geometry and velocity boundary condition have the same principal coordinate plane symmetries but are not axially symmetric.
	Total number of surface elements in that portion of the surface which is nonredundant with respect to axial symmetry. This dimension is equal to the sum of n (see pages 12,13) over all surface regions.	Structural surface geometry <u>and</u> velocity boundary condition are axially symmetric.
D2	Maximum number of rows of each matrix $[M_{ij}]$ and $[B_{ij}]$ (see page 21) that will be stored in core at any one time. Note: D2 = the order of the matrix; corresponds to totally in-core matrix operations.	All

Dimension	Value	Application Condition
D3	Total number of surface elements in the surface model.	Neither the velocity boundary condition nor the structural surface geometry have principal coordinate plane symmetry.
	Total number of surface elements used to model the portion of structural surface which is nonredundant with respect to principal coordinate planes of symmetry.	Structural surface geometry and velocity boundary condition have the same principal coordinate plane symmetries and may or may not be axially symmetric.
D4	Total number of surface regions (see page 9) used to model that portion of structural surface which is nonredundant with respect to principal coordinate planes of symmetry.	Structural surface geometry is axially symmetric.
D5	Number of radial points of longitude (see page 23, Item 4) defining selected field points.	Structural surface is <u>not</u> axially symmetric and the near-field pressure calculation has been selected.
	Maximum number m (see page 13) specified for any region of the surface model.	Structural surface <u>is</u> axially symmetric and only surface pressures or surface pressures and far-field pressures are being calculated.
	Maximum of the two values defined above.	The structural surface <u>is</u> axially symmetric and surface <u>and</u> near-field pressures are being calculated.
D6	Same as D5	Structural surface geometry is axially symmetric and the velocity boundary condition given by Equation (12) (page 20) has been selected.
D7	Maximum value of n (see page 12) which is specified for any region in the surface model.	Same as the above.

Dimension	Value	Application Condition
D8	Same as D1	Surface dynamic mobility-data q_{ij} (see page 5) are being incorporated in the surface pressure calculation.
D9	Maximum number of columns of the matrix product $[q_{ij}][A_{jj}]$ (see Equation (7)) that will be stored in core at any one time. Note: D9 = the order of the matrix; corresponds to totally in-core matrix operations.	Same as the above.
D10	Same as D2	Same as the above.
D11	Same as D3	Same as the above.
D12	Total number of near-field points selected.	Near-field pressure calculation has been selected.
D13	Number of colatitudes (see page 23, Item 3) selected in defining far-field points.	Far-field pressure calculation has been selected.
D14	Number of longitudes (see page 23, Item 4) selected in defining far-field points.	Same as the above.

The user specifies only those dimension parameters appropriate to a particular application. In other words, when no one of the criteria for a dimension parameter is met, it is considered blank or zero in the data input. The parameters will always include as a minimum the set D1, D2, and D3. Additional parameters will depend on the type of surface geometry involved, velocity boundary data, and whether field pressures are calculated. For example, if surface, near-field, and far-field pressures are to be computed using an assumed, in-fluid velocity boundary condition with a nonaxially symmetric surface, the parameters would be D1, D2, D3, D5, D12, D13, and D14.

Data formats for specifying dimension parameters are given in the section entitled DATA FORMATS.

OPTION FOR INDUCED MASS CALCULATION

Once the surface pressure distribution $\{\bar{p}_i\}$ corresponding to a particular velocity boundary condition $\{\bar{v}_i\}$ has been determined, various quantities of interest can be calculated apart from field pressures. One of these quantities is the induced mass for a prescribed vibrational mode of a body.

The body is considered to be surrounded by a fluid which tends to infinity, there to be limited by a closed, rigid spherical surface. The basis for computing induced mass is an expression[5] for total energy increment W in the fluid as the vibration velocity goes from zero to its maximum value

$$W = \frac{1}{2\omega} \iint_S \ell(p)\ v\ dS \tag{17}$$

where S = closed surface of the body

v = normal surface velocity

$\ell(p)$ = imaginary part of surface pressure

ω = angular frequency of vibration

If the fluid is assumed incompressible ($c \to \infty$ and $k \to 0$), the total energy is entirely kinetic

$$W = T = \frac{1}{2\omega} \iint_S \ell(p)\ v\ dS \tag{18}$$

and equals the maximum kinetic energy of the fluid.

Substituting nondimensional forms for pressure and velocity, $\bar{p}$ and $\bar{v}$ (page 4), into Equation (18), one obtains

$$T = \frac{\rho c v_0^{\,2}}{2\omega} \iint_S \ell(\bar{p})\bar{v}\ dS = \frac{1}{2}\, v_0^{\,2} \left[\rho/k \iint_S \ell(\bar{p})\bar{v}\ dS\right] \tag{19}$$

The bracketed quantity is interpreted as the induced mass of the vibration mode.

When the option for induced mass is invoked, XWAVE provides a numerical approximation to the bracketed quantity in Equation (19):

$$M_v \sim A \left(\rho/k \sum_{i=1}^{N} \ell(\bar{p}_i) \cdot \bar{v}_i \cdot \Delta S_i \right) \qquad (20)$$

where M_v = induced mass

N = number of basic surface elements with respect to principal coordinate symmetry or antisymmetry planes

ρ = fluid density

A = integer multiplier dependent on the number of principal coordinate symmetry planes

ΔS_i = area of the ith surface element

A detailed test of the induced mass capability of XWAVE for the case of rigid body vibration of cylinders has been documented.* A typical example from that application is presented in the section entitled EXAMPLE CALCULATIONS.

OPTION FOR SELF-RADIATION IMPEDANCE CALCULATION

A second quantity of interest that can be calculated by using the surface pressure distribution is the self-radiation impedance of a vibrating surface. The vibrating surface may be the entire closed surface of a body or a portion of it, the remainder being considered rigid.

The self-radiation impedance, which will be denoted by $\bar{Z}_{11}$, is the acoustic radiation force per unit velocity acting on the portion of surface that is vibrating

$$\bar{Z}_{11} = F_{11}/v_1 \qquad (21)$$

---

*See the double asterisk footnote on page 3.

where

$$F_{11} = \int_{S_1} p_1 \, dS_1 \tag{22}$$

and

S_1 = vibrating surface
v_1 = surface normal velocity of the vibrating surface
p_i = complex-valued pressure on S_1

The normalized form of Equation (21) used for the calculation is

$$Z_{11} = F_{11}/\rho c A_1 v_1 \tag{23}$$

where A_1 is the area of the vibrating surface S_1. Substituting the nondimensional pressure ($\bar{p}_1 = p_1/\rho c v_1$) into the expression for F_{11} then yields

$$Z_{11} = \int_{S_1} \bar{p}_1 \, dS_1/A_1 \tag{24}$$

When the option for radiation impedance is designated, XWAVE provides the following numerical evaluation of Equation (24):

$$Z_{11} \sim \left(\sum_{i=1}^{N} \bar{p}_i \, \Delta S_{1_i} \right) \Big/ \left(\sum_{i=1}^{N} \Delta S_{1_i} \right) \tag{25}$$

where N is the number of basic surface elements (with respect to principal coordinate symmetry or antisymmetry planes) representing the vibrating surface S_1 and ΔS_{1_i} is the area of the ith surface element of S_1.

This option of XWAVE has been applied to the calculation of the self-radiation impedance of a ring-shaped piston vibrating in a spheroidal baffle. An example from this series of calculations is given in the section entitled EXAMPLE CALCULATIONS.

DATA FORMATS

This section summarizes all XWAVE data relating to calculations involving vibrating structural surfaces and indicates how the data are prepared for reading by the program. Data items which have been discussed in detail in prior sections of this report are referenced to the appropriate pages.

Data card type designations indicated by "   " refer to the data input forms (see the appendix) which have been prepared for use with XWAVE.

• "PROBLEM TITLE" CARD

Columns	Contents
1-12	Blank
13-72	General title associated with the run

• "CASE TITLE" CARD

Columns	Contents
1-12	Blank
13-72	Subtitle associated with the run

• "DIMENSIONS" CARD (pages 24-26)

1- 4	D1
5- 8	D2
9-12	D3
13-16	D4
17-20	D5
21-24	D6
25-28	D7
29-32	D8
33-36	D9
37-40	D10
41-44	D11
45-48	D12
49-52	D13
53-56	D14

• "MISCELLANEOUS DATA" CARD

Columns	Contents	Description
1- 8	k	Wave number of the sound pressure wave, = ω/c
9-16		Blank
17-24	c	Speed of sound in the fluid
25-32	ρ	Fluid density
33-40	$\mathcal{R}$ (H)	Real part of relaxation factor H
41-48	ℓ (H)	Imaginary part of H
49-52	iteration limit	Upper bound on the number of iterations to be carried out in the solution for surface pressures (page 21)
53-60	convergence criterion = ϵ	A number through which the user may select the precision of the surface pressure solution, assuming of course that a convergent solution exists for the particular application (page 21)

• "PROGRAM OPTIONS" CARD

Columns	Contents	Description
1- 4		OPT1: Selector for structure-fluid interaction effect
	0000	Effect is not to be included in the calculation and the normal surface in-fluid velocity is to be specified
	0001	Effect is to be included and the surface in-vacuo mobility coefficients and in-vacuo surface normal velocity for the vibration mode are input (pages 5,8,9,19)
5- 8	0000	OPT2: Structural surface is not a surface of revolution
	0001	Structural surface is a surface of revolution

9-12		OPT3: Selector for surfaces of revolution Structural surface is:
	0000	Piecewise conical shell (pages 9,10)
	0001	Cylinder
	0002	Sphere
	0003	Ellipse
13-16		OPT4: Selector for surface velocity distribution Velocity distribution is:
	0000	Arbitrary and will be read in from cards for each station
	0001	Uniform over entire surface
	0002	Of the form $v_0 \psi(z) \cos M\theta$ (page 20)
	0003	Generated for rigid body motion of structure in the x-coordinate direction
	0004	Uniform over each region of the surface model (pages 9,10)
17-20		OPT5: Reserved for later use
21-24		OPT6:
	=0000	Surface geometric data (page 8) and velocity boundary condition data are read in from cards for each station
	≠0000	Automatic generation of surface geometric data
25-28		OPT7: Selector for near-field point data
	=0000	Coordinates (x-y-z) of near- or intermediate-field points are to be read in from cards
	=0001	Automatic generation of near- or intermediate-field point coordinates
29-32		OPT8:
	=0000	Surface pressures and near- or intermediate-field pressures are to be calculated

	0001	Only surface pressures are to be calculated
	0002	Surface pressures and far-field pressures are to be calculated
33-36		OPT9: Selector for induced mass or self-radiation impedance calculation
	0000	Neither quantity is computed
	0001	Induced mass is calculated
	0002	Self-radiation impedance is calculated
37-40		OPT10: Selector for far-field point data
	0000	Coordinates (ψ,ϕ) of far-field points (see Figure 13) are to be read from cards
	0001	Automatic generation of far-field point coordinates

- "SYMMETRY OPTIONS" CARD

Columns	Contents	Description
1- 4	0002	yz-plane (see Figure 12) symmetry
	0003	yz-plane antisymmetry
5- 8	0004	xz-plane symmetry
	0005	xz-plane antisymmetry
9-12	0001	Longitudinal (xy-plane) symmetry
	0002	Longitudinal antisymmetry
13-16	0000	No rotational (z-axis) symmetry
	0001	Rotational symmetry

- "NUMBER OF REGIONS" CARD

Columns	Contents	Description
1- 4		Total number of surface regions (pages 9,10,15) used in modeling that portion of the structural surface which is nonredundant with respect to the xy-plane

• "REGION: EXTENT AND MODELING" CARD (piecewise conical shell surface; see Figure 5)

Columns	Contents	Description
1- 8	r_1	Radii bounding the surface region
9-16	r_2	
17-24	θ_1	Angles specifying the circumferential extent of the surface region; except for regions capping the ends of a body (θ_1 = 0 degrees, θ_2 = 360 degrees), the extent is that portion of a region which is nonredundant with respect to principal coordinate symmetry planes
25-32	θ_2	
33-40	z_1	Define region extent on the z-axis
41-48	z_2	
49-52	n	Control automatic modeling of region into stations (see page 13)
53-56	m	
57-64		Parameter designating direction of outward normals to regions which are vertical to the z-axis; for example, rings and disks (Figure 6)
	=1.0	Normal points in z^+ direction
	=-1.0	Normal points in z^- direction

• "REGION: EXTENT AND MODELING" CARD (prolate spheroid and spherical shell surface; see Figure 10)

Columns	Contents	Description
1- 8		Blank
9-16		Blank
17-24	θ_1	Same as given for these parameters with the piecewise conical shell surface case above
25-32	θ_2	
33-40	ϕ_1	Define extent of the region in colatitude
41-48	ϕ_2	

49-52	n	Control automatic modeling of region into stations (see pages 16,17, Figure 11)
53-56	m	

"NORMAL SURFACE VELOCITY" CARD

Columns	Contents	Description
1- 8	$\bar{v}_n$(Real)	Real part of the normal surface in-fluid velocity which is to be assigned each station (Figures 8 and 11) in a region
11-18	$\bar{v}_n$(Imag.)	Imaginary part of the above velocity

"PARAMETER CARD 'A' FOR ASSUMED VELOCITY DISTRIBUTION" (see page 20)

Columns	Contents	Description
1- 6	v_0(Real)	Real part of constant velocity amplitude for the vibration mode
7-12	v_0(Imag.)	Imaginary part of the constant velocity amplitude
13-16	M	Integer constant associated with the vibration mode
	=0	Longitudinal and circumferentially symmetric modes
	=1	Flexural modes
	>1	Lobar modes

• "PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION" (see page 20)

Columns	Contents	Description
1- 6		Real part of $\psi(z)_i$
7-12		Imaginary part of $\psi(z)_i$
		where $\psi(z)_i$ designates a
13-18		discretized point of the function $\psi(z)$ assigned to the ith circumferential band of the surface model (for example, Figure 7)
19-24		
.		
.		
.		
61-66		The ordering of bands is from
67-72		the left (z^-) end of the body
		to the right (z^+) end

• "ELLIPSE SEMI-AXIS SPECIFICATION" CARD

Columns	Contents	Description
1- 8	AA	Semimajor axis
9-16	BB	Semiminor axis

• "SPHERE RADIUS SPECIFICATION" CARD

1- 8		Radius of a spherical surface

• "SURFACE GEOMETRIC DATA" CARD (see page 8)

1- 8		Station number
9-16		Station area
17-24, 25-32, 33-40		x-, y-, z-coordinates of station base point
41-48, 49-56, 57-64	n_x, n_y, n_z	x-, y-, z-coordinates of a unit outward (from surface) pointing normal vector at station base point
65-72		Local curvature of station surface at the base point

• "IN-VACUO SURFACE MOBILITY COEFFICIENTS" CARD (see pages 5,8,9,19)

Card Columns	Contents	Description
1-16		Real part of $q_{i,j}$
17-32		Imaginary part of q_{ij}
33-48		Real part of $q_{i+1,j}$
49-64		Imaginary part of $q_{i+1,j}$

In the most general sense, the mobility coefficient q_{ij} represents the normal velocity response at station i due to a normal unit force at frequency ω acting at station j

In applications involving symmetric surfaces and symmetric vibrational loadings, the data input q_{ij} may

represent the mutual influence of groups of stations on one another; for example, in the case of axially symmetric surfaces with ring loads, each q_{ij} would be the velocity response of band (see Figure 7) i due to a unit ring load at band j

• "IN-VACUO NORMAL SURFACE VELOCITIES" CARD (pages 5,19)

For fluid-structure interaction applications, the surface normal velocities for the set of stations representing the nonredundant portion of the surface model are read into the program from a tape or a series of cards. The data format for each card image or card is:

Columns	Contents	Description
1- 8	$\bar{U}_n$(Real)	Real part of in-vacuo velocity at station i
11-18	$\bar{U}_n$(Imag.)	Imaginary part of in-vacuo velocity at station i

The ordering of the velocity input is according to the station numbering shown in Figure 9.

• "AUTOMATIC FIELD POINT GENERATION" CARD (pages 22,23)

Columns	Contents	Description
1- 3	NFLAT	Number of colatitudes at which field points are to be generated
4- 6	NFLNG	Number of longitude points to be generated at each colatitude specified above
10-17	LAT1	Initial colatitude
18-25	LAT2	Final colatitude
26-33	LONG1	Initial longitude
34-41	LONG2	Final longitude
42-49	RADIUS	Radius of spherical surface on which field points are to be generated

• "ARBITRARY FIELD POINT SPECIFICATION" CARD (pages 22,23)

Columns	Contents	Description
1- 8	x_F	x-, y-, z-coordinates of field point
9-16	y_F	
17-24	z_F	

• "AUTOMATIC FAR-FIELD POINT GENERATION" CARD (pages 22,23)

1- 3	NFFLAT	Number of colatitudes, beginning with 0 degrees, at which far-field points are to be generated
4- 6	NFFLNG	Number of longitude points to be generated at each colatitude (excepting 0 and 180 degrees) specified above
10-17	LATLIM	Limit to the range of colatitudes at which points are to be generated
18-25	LONGLIM	Limit to the range of longitudes at which points are to be generated at each colatitude excepting 0 and 180 degrees

• "ARBITRARY FAR-FIELD POINT SPECIFICATION" CARD (page 22)

Columns	Contents	Description
1- 8	ψ_{FF}	Colatitude of far-field point
9-16	ϕ_{FF}	Longitude of far-field point

The precise ordering of the various types of data described here are indicated by the input forms in the appendix. At present there are two basic orderings depending on application.

For cases involving an assumed in-fluid velocity boundary condition, the data on form 1 is followed by the surface model and velocity data from one of the pairs of forms, 2,3; 4,5; 6,8; 7,8; 9,10; or form 11, and then data for the near- and/or far-field calculation.

For cases where the structure-fluid interaction effect is to be calculated and the in-vacuo surface velocity and mobility data are on punched cards, these data are placed between the surface model data from the above-mentioned pairs of forms and the data for field points. If the surface velocity and mobility data are stored on internal files (disk), the surface model data are followed directly by the field data.

EXAMPLE CALCULATIONS

CALCULATION OF FAR-FIELD SOUND PRESSURES

The first problem is taken from an early test series* in which XWAVE was used to calculate far-field sound pressures from a radially vibrating cylinder with fixed end caps. The calculation is performed for the case kA = 1, kB/2 = 2, where we select k = 10 and the cylinder dimensions A and B as shown in Figure 14.

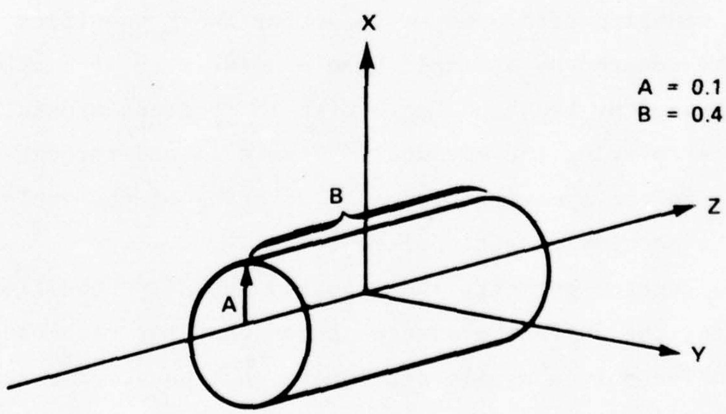

Figure 14 - Geometry of Finite Cylinder

Since there are three principal coordinate planes of symmetry for the surface geometry and velocity boundary condition, only one-eighth of the surface is specified as a basis for generation of the total surface acoustic model. The specified portion of surface is subdivided into two regions; see Figure 15.

---

*See the single asterisk footnote on page 3.

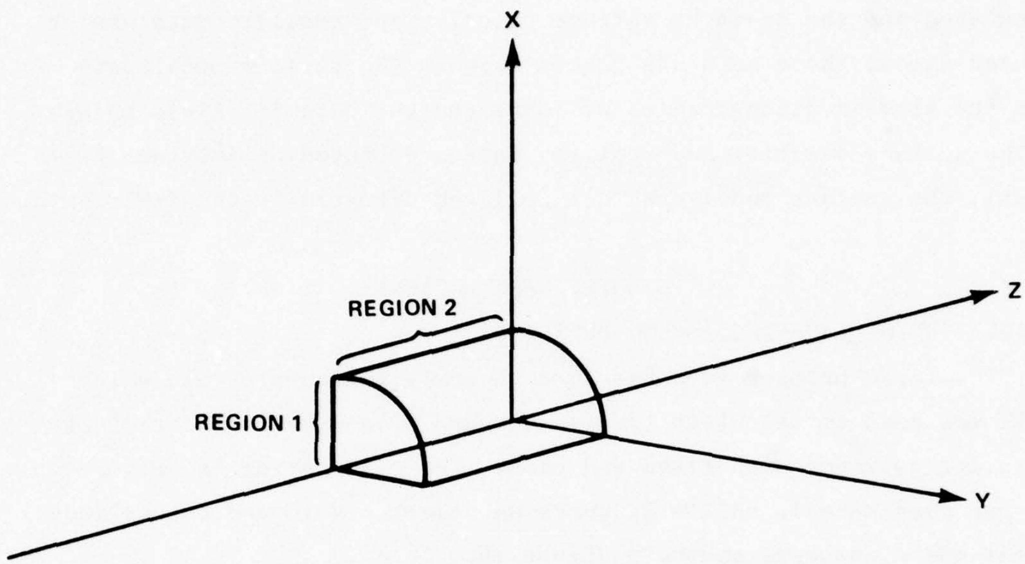

Figure 15 - Portion of Cylindrical Surface Subdivided into Regions

The region modeling data used as input for XWAVE specifies that Region 1 shall be covered by a single band of area with 15 circumferential stations and Region 2 by two bands each with 15 stations around. This gives 45 stations covering the surface in Figure 15 and through their reflected images in the symmetry planes, a covering of the whole surface by 8 x 45 = 360 effective acoustic elements.

Because the surface geometry and velocity boundary condition are axially symmetric, the surface pressure is constant for each band and hence calculated for only a single station in each band. The station is the first one in each band (see pages 14,15, and 19 (top)) as indicated in the XWAVE printout for surface boundary condition and pressures. Thus for this problem, we are required to solve only a system of three equations for the surface pressure. Dimension parameter D2 (see page 24) specifies that the entire matrix will be in-core during coefficient generation and solution time.

We request that the iterative process terminate when either a convergence criterion 0.0001 (pages 21, 22) or a limit of 30 iterations is met.

ALL APPLICATIONS

TITLE EXAMPLE PROBLEM 1 — DATE ____

PROBLEM ____ — SHEET 1 OF 3

XWAVE DATA

PROBLEM TITLE

FINITE CYLINDER - RADIUS, A = 0.1, LENGTH, B = 0.4 (columns 13–72)

CASE TITLE

UNIT VIBRATION OF LATERAL SURFACE, KA = 1, FAR-FIELD RADIATION (columns 13–72)

DIMENSIONS FOR XWAVE

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
0003	0009	0045	0002	0015								0010	0001
1	5	9	13	17	21	25	29	33	37	41	45	49	53 56

MISCELLANEOUS DATA

k		c	ρ	H (REAL)	H (IMAG)	ITERATION LIMIT	CONVERGENCE CRITERION
10.				0.5	0.	0030	0.0001
1	9	17	25	33	41	49	53 60

PROGRAM OPTIONS

OPT1	OPT2	OPT3	OPT4	OPT5	OPT6	OPT7	OPT8	OPT9	OPT10
0000	0001	0001	0004	0000	0001	0001	0002	0000	0001
1	5	9	13	17	21	25	29	33	37 40

SYMMETRY OPTIONS

YZ-PLANE	XZ-PLANE	LONG.	RADIAL
		0001	0001
1	5	9	13 16

DATA INPUT FORM (1)

PIECEWISE CONICAL SHELL SURFACE

TITLE EXAMPLE PROBLEM 1   DATE ______

PROBLEM ______   SHEET 2 OF 3

XWAVE DATA

NUMBER OF REGIONS

1–4
0002

REGION: EXTENT AND MODELING

r_1 (1)	r_2 (9)	θ_1 (17)	θ_2 (25)	z_1 (33)	z_2 (41)	n (49)	m (53)	SIGN (57)	(64)
0.0	0.1	0.0	90.0	-0.2	-0.2	0001	0015	-1.0	

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL) (1)	(8)	$\bar{V}_n$ (IMAG.) (11)	(18)
0.0	ΔΔ	0.0	

REGION: EXTENT AND MODELING

r_1 (1)	r_2 (9)	θ_1 (17)	θ_2 (25)	z_1 (33)	z_2 (41)	n (49)	m (53)	SIGN (57)	(64)
0.1	0.1	0.0	90.0	-0.2	0.0	0002	0015		

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL) (1)	(8)	$\bar{V}_n$ (IMAG.) (11)	(18)
1.0	ΔΔ	0.0	

REGION: EXTENT AND MODELING

r_1 (1)	r_2 (9)	θ_1 (17)	θ_2 (25)	z_1 (33)	z_2 (41)	n (49)	m (53)	SIGN (57)	(64)

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL) (1)	(8)	$\bar{V}_n$ (IMAG.) (11)	(18)
	ΔΔ		

DATA INPUT FORM (2)

FAR-FIELD PRESSURE CALCULATION

TITLE EXAMPLE PROBLEM 1 DATE ______

PROBLEM ______ SHEET 3 OF 3

XWAVE DATA

AUTOMATIC FAR-FIELD POINT GENERATION

NFFLAT	NFFLNG	LATLIM	LONGLIM
010	001	000	90.0	0.0
1	4	7	10	18	25

ARBITRARY FAR-FIELD POINT SPECIFICATION

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

DATA INPUT FORM (15)

```
ELAPSED TIME AT ENTRY INTO XWAVE =     2.568E+01 SECONDS

THERE ARE 041023(OCTAL) WORDS OF OPEN-CORE AVAILABLE FOR THIS PROBLEM

CM REDUCED TO 041000(OCTAL)
```

```
XWAVE   SEPTEMBER 1976

FINITE CYLINDER - RADIUS, A=0.1, LENGTH, B=0.4
UNIT VIBRATION OF LATERAL SURFACE, KA=1, FAR-FIELD RADIATION

DIMENSIONS FOR ARRAYS

 DIMENSION  1 =   3
 DIMENSION  2 =   3
 DIMENSION  3 =  45
 DIMENSION  4 =   2
 DIMENSION  5 =  15
 DIMENSION  6 =   1
 DIMENSION  7 =   1
 DIMENSION  8 =   1
 DIMENSION  9 =   1
 DIMENSION 10 =   1
 DIMENSION 11 =   1
 DIMENSION 12 =   1
 DIMENSION 13 =  10
 DIMENSION 14 =   1

WAVE NUMBER K =  1.0000E+01

OPTION DATA
OP1  OP2  OP3  OP4  OP5  OP6  OP7  OP8  OP9  OP10
 0    1    1    4    0    1    1    2    0    1

SURFACE GEOMETRY AND BOUNDARY CONDITION SYMMETRIES

  ROTATIONAL SYMMETRY ABOUT Z-AXIS

  LONGITUDINAL SYMMETRY
```

SURFACE MODEL GEOMETRY

SURFACE ELEMENT NO.	ELEMENT BASE POINT COORDINATES X	Y	Z	INVERSE CURVATURE AT BASE POINT	AREA OF ELEMENT	COORDINATES OF UNIT OUTWARD NORMAL AT BASE POINT X	Y	Z
1	2.6168E-03	4.9931E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
2	7.8217E-03	4.9384E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
3	1.2941E-02	4.8296E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
4	1.7918E-02	4.6679E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
5	2.2700E-02	4.4550E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
6	2.7232E-02	4.1934E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
7	3.1466E-02	3.8857E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00

8	3.5355E-02	3.5355E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
9	3.8857E-02	3.1466E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
10	4.1934E-02	2.7232E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
11	4.4550E-02	2.2700E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
12	4.6679E-02	1.7918E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
13	4.8296E-02	1.2941E-02	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
14	4.9384E-02	7.8217E-03	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
15	4.9931E-02	2.6168E-03	-2.0000E-01	0.	5.2360E-04	0.	0.	-1.0000E+00
16	5.2336E-03	9.9863E-02	-1.5000E-01	2.0000E-01	1.0472E-03	5.2336E-02	9.9863E-01	0.
17	1.5643E-02	9.8769E-02	-1.5000E-01	2.0000E-01	1.0472E-03	1.5643E-01	9.8769E-01	0.
18	2.5882E-02	9.6593E-02	-1.5000E-01	2.0000E-01	1.0472E-03	2.5882E-01	9.6593E-01	0.
19	3.5837E-02	9.3358E-02	-1.5000E-01	2.0000E-01	1.0472E-03	3.5837E-01	9.3358E-01	0.
20	4.5399E-02	8.9101E-02	-1.5000E-01	2.0000E-01	1.0472E-03	4.5399E-01	8.9101E-01	0.
21	5.4464E-02	8.3867E-02	-1.5000E-01	2.0000E-01	1.0472E-03	5.4464E-01	8.3867E-01	0.
22	6.2932E-02	7.7715E-02	-1.5000E-01	2.0000E-01	1.0472E-03	6.2932E-01	7.7715E-01	0.
23	7.0711E-02	7.0711E-02	-1.5000E-01	2.0000E-01	1.0472E-03	7.0711E-01	7.0711E-01	0.
24	7.7715E-02	6.2932E-02	-1.5000E-01	2.0000E-01	1.0472E-03	7.7715E-01	6.2932E-01	0.
25	8.3867E-02	5.4464E-02	-1.5000E-01	2.0000E-01	1.0472E-03	8.3867E-01	5.4464E-01	0.
26	8.9101E-02	4.5399E-02	-1.5000E-01	2.0000E-01	1.0472E-03	8.9101E-01	4.5399E-01	0.
27	9.3358E-02	3.5837E-02	-1.5000E-01	2.0000E-01	1.0472E-03	9.3358E-01	3.5837E-01	0.
28	9.6593E-02	2.5882E-02	-1.5000E-01	2.0000E-01	1.0472E-03	9.6593E-01	2.5882E-01	0.
29	9.8769E-02	1.5643E-02	-1.5000E-01	2.0000E-01	1.0472E-03	9.8769E-01	1.5643E-01	0.

30	9.9863E-02	5.2336E-03	-1.5000E-01	2.0000E-01	1.0472E-03	9.9863E-01	5.2336E-02	0.
31	5.2336E-03	9.9863E-02	-5.0000E-02	2.0000E-01	1.0472E-03	5.2336E-02	9.9863E-01	0.
32	1.5643E-02	9.8769E-02	-5.0000E-02	2.0000E-01	1.0472E-03	1.5643E-01	9.8769E-01	0.
33	2.5882E-02	9.6593E-02	-5.0000E-02	2.0000E-01	1.0472E-03	2.5882E-01	9.6593E-01	0.
34	3.5837E-02	9.3358E-02	-5.0000E-02	2.0000E-01	1.0472E-03	3.5837E-01	9.3358E-01	0.
35	4.5399E-02	8.9101E-02	-5.0000E-02	2.0000E-01	1.0472E-03	4.5399E-01	8.9101E-01	0.
36	5.4464E-02	8.3867E-02	-5.0000E-02	2.0000E-01	1.0472E-03	5.4464E-01	8.3867E-01	0.
37	6.2932E-02	7.7715E-02	-5.0000E-02	2.0000E-01	1.0472E-03	6.2932E-01	7.7715E-01	0.
38	7.0711E-02	7.0711E-02	-5.0000E-02	2.0000E-01	1.0472E-03	7.0711E-01	7.0711E-01	0.
39	7.7715E-02	6.2932E-02	-5.0000E-02	2.0000E-01	1.0472E-03	7.7715E-01	6.2932E-01	0.
40	8.3867E-02	5.4464E-02	-5.0000E-02	2.0000E-01	1.0472E-03	8.3867E-01	5.4464E-01	0.
41	8.9101E-02	4.5399E-02	-5.0000E-02	2.0000E-01	1.0472E-03	8.9101E-01	4.5399E-01	0.
42	9.3358E-02	3.5837E-02	-5.0000E-02	2.0000E-01	1.0472E-03	9.3358E-01	3.5837E-01	0.
43	9.6593E-02	2.5882E-02	-5.0000E-02	2.0000E-01	1.0472E-03	9.6593E-01	2.5882E-01	0.
44	9.8769E-02	1.5643E-02	-5.0000E-02	2.0000E-01	1.0472E-03	9.8769E-01	1.5643E-01	0.
45	9.9863E-02	5.2336E-03	-5.0000E-02	2.0000E-01	1.0472E-03	9.9863E-01	5.2336E-02	0.

```
SURFACE NORMAL VELOCITY BOUNDARY CONDITION

                                            SURFACE VELOCITIES(   REAL PART, IMAGINARY PART   )

REGION =  1
                      V(  1)
              0.             0.

REGION =  2
                      V( 16)                             V( 31)
              1.0000E+00     0.            1.0000E+00    0.
```

```
ENTER SUBROUTINE FOR ITERATIVE SOLUTION FOR SURFACE PRESSURE

 REQUESTED LIMIT ON NUMBER OF ITERATIONS =  30

 RELAXATION FACTOR SPECIFIED IS

   REAL PART  IMAGINARY PART
  5.0000E-01      0.

 CONVERGENCE CRITERION =  1.0000E-04


BEGIN ITERATION

 TIME =       2.674E+01 SECONDS

 MAXIMUM DIFFERENCE BETWEEN COMPONENTS

       OF SUCCESSIVE VECTORS
            1.0632E+00

            2.9439E-01

            1.3193E-01

            6.3455E-02

            3.2199E-02

            1.7212E-02

            9.7159E-03

            5.7629E-03

            3.5482E-03

            2.2384E-03

            1.4332E-03

            9.2592E-04

            6.0167E-04

            3.9250E-04

            2.5677E-04

            1.6830E-04

            1.1046E-04

            7.2554E-05

 ITERATION TERMINATED BY CONVERGENCE CRITERION BEING MET


 TIME AT TERMINATION IS       2.685E+01 SECONDS
```

```
                         SURFACE PRESSURES(   REAL PART, IMAGINARY PART   )

REGION =  1
                 P(  1)
           2.6964E-01   5.1175E-01

REGION =  2
                 P( 16)                    P( 31)
           5.3128E-01  -5.2185E-01    8.1780E-01  -6.3701E-01

FAR-FIELD PRESSURES AT THE SURFACE OF A LARGE SPHERE CENTERED AROUND THE BODY

COLATITUDE = 0.        DEG

     LONGITUDE        (0.       DEG)

             REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY
           1.4841E-01  -1.5405E-02

COLATITUDE = 1.000E+01 DEG

     LONGITUDE        (0.       DEG)

             REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY
           1.4943E-01  -1.6800E-02

COLATITUDE = 2.000E+01 DEG

     LONGITUDE        (0.       DEG)

             REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY      REAL      IMAGINARY
           1.5185E-01  -2.0957E-02

COLATITUDE = 3.000E+01 DEG
```

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.5400E-01	-2.7727E-02						

COLATITUDE = 4.000E+01 DEG

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.5387E-01	-3.6687E-02						

COLATITUDE = 5.000E+01 DEG

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.5017E-01	-4.7000E-02						

COLATITUDE = 6.000E+01 DEG

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.4308E-01	-5.7399E-02						

COLATITUDE = 7.000E+01 DEG

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.3456E-01	-6.636[illegible]E-02						

COLATITUDE = 8.000E+01 DEG

LONGITUDE (0. DEG)

REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY	REAL	IMAGINARY
1.2760E-01	-7.2448E-02						

```
COLATITUDE = 9.000E+01 DEG

     LONGITUDE        (0.       DEG)

                 REAL       IMAGINARY       REAL       IMAGINARY       REAL       IMAGINARY       REAL       IMAGINARY
              1.2491E-01  -7.4602E-02

ELAPSED TIME AT EXIT FROM XWAVE =    2.918E+01  SECONDS
```

Normalizing the magnitudes of the computed far-field pressures to the largest magnitude yields the curve indicated by x in Figure 16 (reproduced from Figure 9 of CMD-24-71). The solid reference curve shows consistency of XWAVE results, using increasingly refined surface models, with published results from another computing method.[6]

CALCULATION OF SELF-RADIATION IMPEDANCE

The second example is an application of XWAVE to calculate the self-radiation impedance (see the section entitled OPTION FOR SELF-RADIATION IMPEDANCE CALCULATION) of a vibrating ring in a spheroidal baffle.[2] Figure 17 recalls the geometry for this problem.

The ring is assumed to vibrate radially with unit velocity. The velocity over the baffle is of course zero. In the original investigation, calculations were made for a range of values of the acoustic shape parameter $h \equiv kd/2$. For the illustrative calculation given here, we choose a value of 3.0 for h; this corresponds to the wave number $k = 1.374773$.

As in the first example, there are three principal coordinate planes of symmetry for the surface geometry and boundary condition. The specification of the portion of surface that is to be divided into regions and stations proceeds slightly differently in this case because the ends of the spheroid are modeled by regions consisting of single stations centered about the respective poles; see Figure 18. The data specify the end cap region extending from $\theta = 0$ to $\theta = 360$ degrees rather than to $\theta = 90$ degrees as with Regions 2 and 3 since the only image data obtainable from the basic geometry (for example, coordinates of base point and unit surface normal, etc.) of the single station within the region are for the opposite end through longitudinal reflection.

---

[6] Schenck, H.A., "Improved Integral Formulation for Acoustic Radiation Problems," Journal of the Acoustical Society of America, Vol. 44, No. 1, pp. 41-58 (Jul 1968).

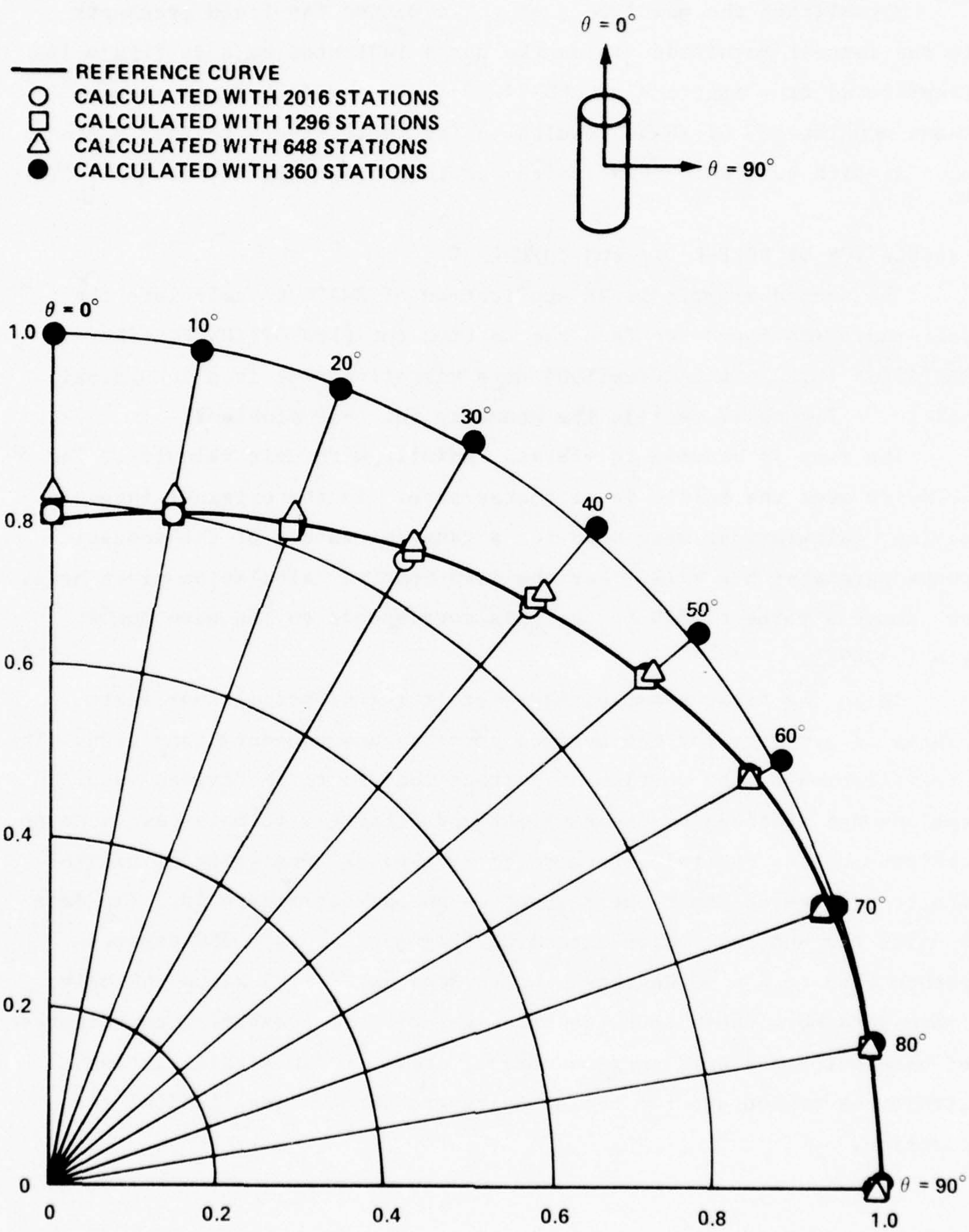

Figure 16 - Normalized Far-Field Pressure Magnitudes for Finite Cylinder Test Calculations with XWAVE

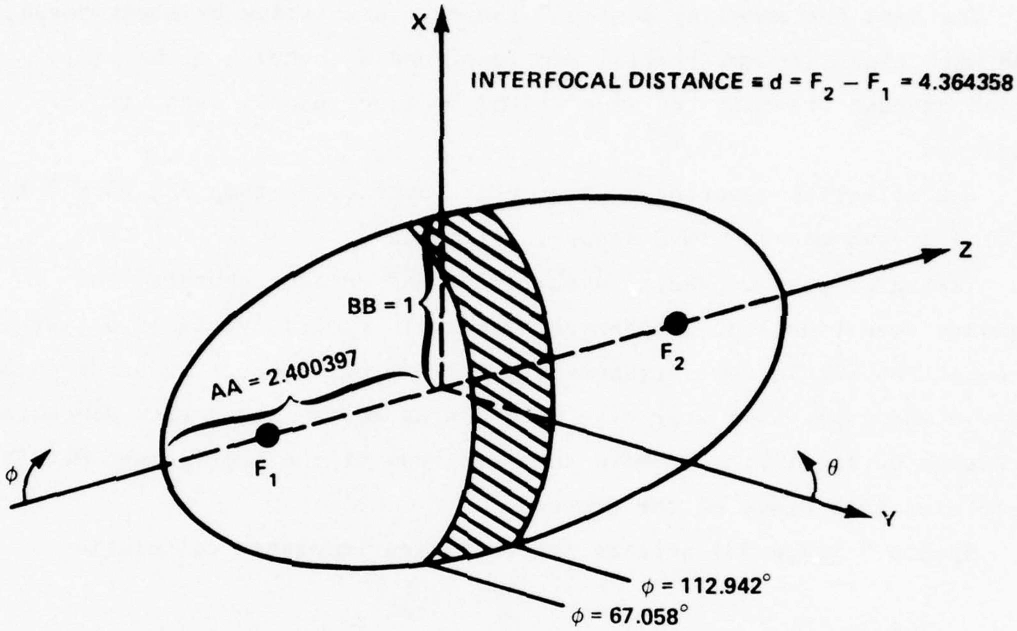

Figure 17 - Geometry for Vibrating Ring in Spheroidal Baffle

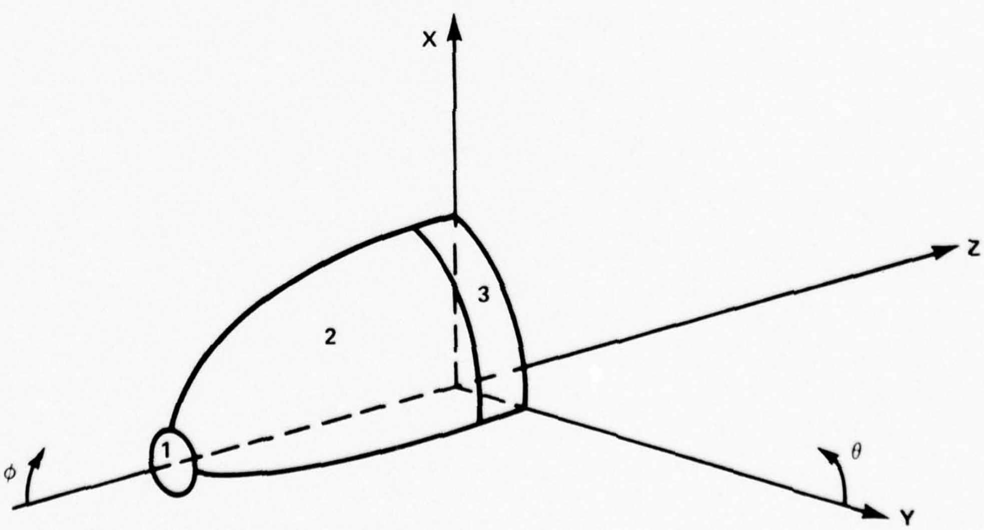

Figure 18 - Surface Regions for Spheroidal Baffle with Ring

The data for modeling Region 2 indicate a covering by eight bands, each with eight circumferential stations, and a covering of Re 3 (which extends one-half the ring width) by three bands, each with 22 stations.

The effective covering of the entire surface is then 8 x [8 x 8 + 3 x 22] + 2 (end caps) = 1042 acoustic elements.

Taking account of radial symmetry of the surface geometry and boundary condition, the program generates the coefficients for a system of 12 equations for surface pressure (12 is the total number of bands including the end cap). The iterative solution is accomplished with dimension parameter D2 specifying no more than two rows of the coefficient matrix in-core at each stage of the process.

Option 9 (page 33) selects the radiation impedance calculation.

ALL APPLICATIONS

TITLE EXAMPLE PROBLEM 2

PROBLEM

DATE

SHEET 1 OF 2

XWAVE DATA

PROBLEM TITLE

VIBRATING RING IN SPHEROIDAL BAFFLE

13 72

CASE TITLE

SELF-RADIATION IMPEDANCE OF RING FOR H= 3.0

13 72

DIMENSIONS FOR XWAVE

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
0012	0002	0131	0003	0022									
1	5	9	13	17	21	25	29	33	37	41	45	49	53 56

MISCELLANEOUS DATA

k		c	ρ	H (REAL)	H (IMAG)	ITERATION LIMIT	CONVERGENCE CRITERION
1.374773				0.5	0.0	0030	0.0001
1	9	17	25	33	41	49	53 60

PROGRAM OPTIONS

OPT1	OPT2	OPT3	OPT4	OPT5	OPT6	OPT7	OPT8	OPT9	OPT10
0000	0001	0003	0004	0000	0001	0001	0001	0002	0000
1	5	9	13	17	21	25	29	33	37 40

SYMMETRY OPTIONS

YZ-PLANE	XZ-PLANE	LONG.	RADIAL
		0001	0001
1	5	9	13 16

DATA INPUT FORM (1)

PROLATE SPHEROIDAL SHELL SURFACE

TITLE EXAMPLE PROBLEM 2

PROBLEM

DATE

SHEET 2 OF 2

XWAVE DATA

ELLIPSE SEMI-AXIS SPECIFICATION

AA	BB
2.400397	1.0
1	9 16

NUMBER OF REGIONS

0003
1 4

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
		0.0	360.0	0.0	1.0	0001	0001
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
0.0		0.0
1	8	11 18

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
		0.0	90.0	1.0	67.058	0008	0008
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
0.0		0.0
1	8	11 18

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
		0.0	90.0	67.058	90.0	0003	0022
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1.0		0.0
1	8	11 18

DATA INPUT FORM (6)

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ELAPSED TIME AT ENTRY INTO XWAVE =     2.550E+01 SECONDS

THERE ARE 041026(OCTAL) WORDS OF OPEN-CORE AVAILABLE FOR THIS PROBLEM

CM REDUCED TO 043600(OCTAL)
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XWAVE SEPTEMBER 1976

VIBRATING RING IN SPHEROIDAL BAFFLE
SELF-RADIATION IMPEDANCE OF RING FOR H=3.0

DIMENSIONS FOR ARRAYS

DIMENSION 1 = 12
DIMENSION 2 = 2
DIMENSION 3 = 131
DIMENSION 4 = 3
DIMENSION 5 = 22
DIMENSION 6 = 1
DIMENSION 7 = 1
DIMENSION 8 = 1
DIMENSION 9 = 1
DIMENSION 10 = 1
DIMENSION 11 = 1
DIMENSION 12 = 1
DIMENSION 13 = 1
DIMENSION 14 = 1

WAVE NUMBER K = 1.3748E+00

OPTION DATA

OP1	OP2	OP3	OP4	OP5	OP6	OP7	OP8	OP9	OP10
0	1	3	4	0	1	1	1	2	0

SURFACE GEOMETRY AND BOUNDARY CONDITION SYMMETRIES

ROTATIONAL SYMMETRY ABOUT Z-AXIS

LONGITUDINAL SYMMETRY

SURFACE MODEL GEOMETRY

SURFACE ELEMENT NO.	ELEMENT BASE POINT COORDINATES X	Y	Z	INVERSE CURVATURE AT BASE POINT	AREA OF ELEMENT	COORDINATES OF UNIT OUTWARD NORMAL AT BASE POINT X	Y	Z
1	0.	0.	-2.4004E+00	8.3320E-01	5.5194E-03	1.7723E-17	2.0510E-10	-1.0000E+00
2	2.0643E-12	2.0359E-01	-2.3466E+00	3.3232E-01	1.5295E-02	4.5024E-02	4.5714E-01	-8.8826E-01
3	6.1136E-02	2.0154E-01	-2.3466E+00	3.3232E-01	1.5295E-02	1.3334E-01	4.3957E-01	-8.8826E-01
4	9.9279E-02	1.8574E-01	-2.3466E+00	3.3232E-01	1.5295E-02	2.1654E-01	4.0511E-01	-8.8826E-01
5	1.3361E-01	1.6280E-01	-2.3466E+00	3.3232E-01	1.5295E-02	2.9141E-01	3.5508E-01	-8.8826E-01
6	1.6280E-01	1.3361E-01	-2.3466E+00	3.3232E-01	1.5295E-02	3.5508E-01	2.9141E-01	-8.8826E-01

7	1.8574E-01	9.9279E-02	-2.3466E+00	3.3232E-01	1.5295E-02	4.0511E-01	2.1654E-01	-8.8826E-01
8	2.0154E-01	6.1136E-02	-2.3466E+00	3.3232E-01	1.5295E-02	4.3957E-01	1.3334E-01	-8.8826E-01
9	2.0959E-01	2.0643E-02	-2.3466E+00	3.3232E-01	1.5295E-02	4.5714E-01	4.5024E-02	-8.8826E-01
10	4.8617E-02	4.9362E-01	-2.0843E+00	1.0319E+00	3.8950E-02	7.9194E-02	8.0407E-01	-5.8924E-01
11	1.4398E-01	4.7465E-01	-2.0843E+00	1.0319E+00	3.8950E-02	2.3454E-01	7.7317E-01	-5.8924E-01
12	2.3382E-01	4.3744E-01	-2.0843E+00	1.0319E+00	3.8950E-02	3.8087E-01	7.1255E-01	-5.8924E-01
13	3.1466E-01	3.8342E-01	-2.0843E+00	1.0319E+00	3.8950E-02	5.1256E-01	6.2456E-01	-5.8924E-01
14	3.8342E-01	3.1466E-01	-2.0843E+00	1.0319E+00	3.8950E-02	6.2456E-01	5.1256E-01	-5.8924E-01
15	4.3744E-01	2.3382E-01	-2.0843E+00	1.0319E+00	3.8950E-02	7.1255E-01	3.8087E-01	-5.8924E-01
16	4.7465E-01	1.4398E-01	-2.0843E+00	1.0319E+00	3.8950E-02	7.7317E-01	2.3454E-01	-5.8924E-01
17	4.9382E-01	4.8617E-02	-2.0843E+00	1.0319E+00	3.8950E-02	8.0407E-01	7.9194E-02	-5.8924E-01
18	6.7602E-02	6.8637E-01	-1.7381E+00	2.0245E+00	5.0859E-02	8.9803E-02	9.1178E-01	-4.0073E-01
19	2.0021E-01	6.5999E-01	-1.7381E+00	2.0245E+00	5.0859E-02	2.6596E-01	8.7675E-01	-4.0073E-01
20	3.2512E-01	6.0825E-01	-1.7381E+00	2.0245E+00	5.0859E-02	4.3189E-01	8.0801E-01	-4.0073E-01
21	4.3754E-01	5.3314E-01	-1.7381E+00	2.0245E+00	5.0859E-02	5.8123E-01	7.0823E-01	-4.0073E-01
22	5.3314E-01	4.3754E-01	-1.7381E+00	2.0245E+00	5.0859E-02	7.0823E-01	5.8123E-01	-4.0073E-01
23	6.0825E-01	3.2512E-01	-1.7381E+00	2.0245E+00	5.0859E-02	8.0801E-01	4.3189E-01	-4.0073E-01
24	6.5999E-01	2.0021E-01	-1.7381E+00	2.0245E+00	5.0859E-02	8.7675E-01	2.6596E-01	-4.0073E-01
25	6.8637E-01	6.7601E-02	-1.7381E+00	2.0245E+00	5.0859E-02	9.1178E-01	8.9803E-02	-4.0073E-01
26	7.9376E-02	8.0591E-01	-1.4083E+00	3.1078E+00	5.0974E-02	9.3836E-02	9.5274E-01	-2.8894E-01
27	2.3508E-01	7.7494E-01	-1.4083E+00	3.1078E+00	5.0974E-02	2.7790E-01	9.1612E-01	-2.8894E-01
28	3.8174E-01	7.1419E-01	-1.4083E+00	3.1078E+00	5.0974E-02	4.5129E-01	8.4430E-01	-2.8894E-01

29	5.1374E-01	6.2599E-01	-1.4083F+00	3.1078E+00	5.0974E-02	6.0733E-01	7.4004E-01	-2.8894E-01
30	6.2599E-01	5.1374E-01	-1.4083F+00	3.1078E+00	5.0974E-02	7.4004E-01	6.0733E-01	-2.8894E-01
31	7.1419E-01	3.8174E-01	-1.4083F+00	3.1078E+00	5.0974E-02	8.4430E-01	4.5129E-01	-2.8894E-01
32	7.7494E-01	2.3508E-01	-1.4083F+00	3.1078E+00	5.0974E-02	9.1612E-01	2.7790E-01	-2.8894E-01
33	8.0591E-01	7.9375E-02	-1.4083F+00	3.1078E+00	5.0974E-02	9.5274E-01	9.3836E-02	-2.8894E-01
34	8.6598E-02	8.7924E-01	-1.1244F+00	4.1803E+00	4.6242E-02	9.5710E-02	9.7176E-01	-2.1568E-01
35	2.5647E-01	8.4545E-01	-1.1244E+00	4.1803E+00	4.6242E-02	2.8345E-01	9.3442E-01	-2.1568E-01
36	4.1648E-01	7.7917E-01	-1.1244F+00	4.1803E+00	4.6242E-02	4.6030E-01	8.6116E-01	-2.1568E-01
37	5.6048E-01	6.8295E-01	-1.1244E+00	4.1803E+00	4.6242E-02	6.1946E-01	7.5482E-01	-2.1568E-01
38	6.8295E-01	5.6048E-01	-1.1244E+00	4.1803E+00	4.6242E-02	7.5482E-01	6.1946E-01	-2.1568E-01
39	7.7917E-01	4.1648E-01	-1.1244E+00	4.1803E+00	4.6242E-02	8.6116E-01	4.6030E-01	-2.1568E-01
40	8.4545E-01	2.5647E-01	-1.1244F+00	4.1803E+00	4.6242E-02	9.3442E-01	2.8345E-01	-2.1568E-01
41	8.7924E-01	8.6598E-02	-1.1244E+00	4.1803E+00	4.6242E-02	9.7176E-01	9.5710E-02	-2.1568E-01
42	9.1116E-02	9.2511E-01	-8.8478E-01	5.2243E+00	4.0857E-02	9.6707E-02	9.8188E-01	-1.6298E-01
43	2.6985E-01	8.8956E-01	-8.8478E-01	5.2243E+00	4.0857E-02	2.8640E-01	9.4415E-01	-1.6298E-01
44	4.3821E-01	8.1982E-01	-8.8478F-01	5.2243E+00	4.0857E-02	4.6509E-01	8.7013E-01	-1.6298E-01
45	5.8973E-01	7.1858E-01	-8.8478E-01	5.2243E+00	4.0857E-02	6.2591E-01	7.6268E-01	-1.6298E-01
46	7.1858E-01	5.8973E-01	-8.8478F-01	5.2243E+00	4.0857E-02	7.6268E-01	6.2591E-01	-1.6298E-01
47	8.1982E-01	4.3821E-01	-8.8478F-01	5.2243E+00	4.0857E-02	8.7013E-01	4.6509E-01	-1.6298E-01
48	8.8956E-01	2.6985E-01	-8.8478E-01	5.2243E+00	4.0857E-02	9.4415E-01	2.8640E-01	-1.6298E-01
49	9.2511E-01	9.1116E-02	-8.8478E-01	5.2243E+00	4.0857E-02	9.8188E-01	9.6707E-02	-1.6298E-01
50	9.4005E-02	9.5445E-01	-6.7976F-01	6.2567E+00	3.6286E-02	9.7284E-02	9.8774E-01	-1.2289E-01

51	2.7840E-01	9.1777E-01	-6.7976E-01	6.2567E+00	3.6286E-02	2.8811E-01	9.4978E-01	-1.2209E-01
52	4.5210E-01	8.4582E-01	-6.7976E-01	6.2567E+00	3.6286E-02	4.6787E-01	8.7532E-01	-1.2209E-01
53	6.3842E-01	7.4137E-01	-6.7976E-01	6.2567E+00	3.6286E-02	6.2965E-01	7.6723E-01	-1.2209E-01
54	7.4137E-01	6.0842E-01	-6.7976E-01	6.2567E+00	3.6286E-02	7.6723E-01	6.2965E-01	-1.2209E-01
55	8.4582E-01	4.5210E-01	-6.7976E-01	6.2567E+00	3.6286E-02	8.7532E-01	4.6787E-01	-1.2209E-01
56	9.1777E-01	2.7840E-01	-6.7976E-01	6.2567E+00	3.6286E-02	9.4978E-01	2.8811E-01	-1.2209E-01
57	9.5445E-01	9.4005E-02	-6.7976E-01	6.2567E+00	3.6286E-02	9.8774E-01	9.7284E-02	-1.2209E-01
58	9.5868E-02	9.7337E-01	-4.9987E-01	7.3085E+00	3.2833E-02	9.7634E-02	9.9129E-01	-8.8353E-02
59	2.8392E-01	9.3596E-01	-4.9987E-01	7.3085E+00	3.2833E-02	2.8915E-01	9.5320E-01	-8.8353E-02
60	4.6106E-01	8.6259E-01	-4.9987E-01	7.3085E+00	3.2833E-02	4.6955E-01	8.7847E-01	-8.8353E-02
61	6.2049E-01	7.5606E-01	-4.9987E-01	7.3085E+00	3.2833E-02	6.3191E-01	7.6999E-01	-8.8353E-02
62	7.5606E-01	6.2049E-01	-4.9987E-01	7.3085E+00	3.2833E-02	7.6999E-01	6.3191E-01	-8.8353E-02
63	8.6259E-01	4.6106E-01	-4.9987E-01	7.3085E+00	3.2833E-02	8.7847E-01	4.6955E-01	-8.8353E-02
64	9.3596E-01	2.8392E-01	-4.9987E-01	7.3085E+00	3.2833E-02	9.5320E-01	2.8915E-01	-8.8353E-02
65	9.7337E-01	9.5868E-02	-4.9987E-01	7.3085E+00	3.2833E-02	9.9129E-01	9.7634E-02	-8.8353E-02
66	3.5326E-02	9.8910E-01	-3.4308E-01	8.3781E+00	1.0273E-02	3.5628E-02	9.9756E-01	-6.0052E-02
67	1.0580E-01	9.8406E-01	-3.4308E-01	8.3781E+00	1.0273E-02	1.0670E-01	9.9248E-01	-6.0052E-02
68	1.7573E-01	9.7401E-01	-3.4308E-01	8.3781E+00	1.0273E-02	1.7723E-01	9.8234E-01	-6.0052E-02
69	2.4477E-01	9.5899E-01	-3.4308E-01	8.3781E+00	1.0273E-02	2.4686E-01	9.6719E-01	-6.0052E-02
70	3.1256E-01	9.3908E-01	-3.4308E-01	8.3781E+00	1.0273E-02	3.1523E-01	9.4711E-01	-6.0052E-02
71	3.7875E-01	9.1439E-01	-3.4308E-01	8.3781E+00	1.0273E-02	3.8199E-01	9.2221E-01	-6.0052E-02
72	4.4302E-01	8.8504E-01	-3.4308E-01	8.3781E+00	1.0273E-02	4.4681E-01	8.9261E-01	-6.0052E-02

73	5.0503E-01	8.5118E-01	-3.4308E-01	8.3781E+00	1.0273E-02	5.0935E-01	8.5846E-01	-6.0052E-02
74	5.6447E-01	8.1299E-01	-3.4308E-01	8.3781E+00	1.0273E-02	5.6929E-01	8.1994E-01	-6.0052E-02
75	6.2103E-01	7.7065E-01	-3.4308E-01	8.3781E+00	1.0273E-02	6.2634E-01	7.7724E-01	-6.0052E-02
76	6.7442E-01	7.2438E-01	-3.4308E-01	8.3781E+00	1.0273E-02	6.8019E-01	7.3057E-01	-6.0052E-02
77	7.2438E-01	6.7442E-01	-3.4308E-01	8.3781E+00	1.0273E-02	7.3057E-01	6.8019E-01	-6.0052E-02
78	7.7065E-01	6.2103E-01	-3.4308E-01	8.3781E+00	1.0273E-02	7.7724E-01	6.2634E-01	-6.0052E-02
79	8.1299E-01	5.6447E-01	-3.4308E-01	8.3781E+00	1.0273E-02	8.1994E-01	5.6929E-01	-6.0052E-02
80	8.5118E-01	5.0503E-01	-3.4308E-01	8.3781E+00	1.0273E-02	8.5846E-01	5.0935E-01	-6.0052E-02
81	8.8504E-01	4.4302E-01	-3.4308E-01	8.3781E+00	1.0273E-02	8.9261E-01	4.4681E-01	-6.0052E-02
82	9.1439E-01	3.7875E-01	-3.4308E-01	8.3781E+00	1.0273E-02	9.2221E-01	3.8199E-01	-6.0052E-02
83	9.3908E-01	3.1256E-01	-3.4308E-01	8.3781E+00	1.0273E-02	9.4711E-01	3.1523E-01	-6.0052E-02
84	9.5899E-01	2.4477E-01	-3.4308E-01	8.3781E+00	1.0273E-02	9.6719E-01	2.4686E-01	-6.0052E-02
85	9.7401E-01	1.7573E-01	-3.4308E-01	8.3781E+00	1.0273E-02	9.8234E-01	1.7723E-01	-6.0052E-02
86	9.8406E-01	1.0580E-01	-3.4308E-01	8.3781E+00	1.0273E-02	9.9248E-01	1.0670E-01	-6.0052E-02
87	9.8910E-01	3.5326E-02	-3.4308E-01	8.3781E+00	1.0273E-02	9.9756E-01	3.5628E-02	-6.0052E-02
88	3.5565E-02	9.9581E-01	-2.0220E-01	9.5051E+00	9.7981E-03	3.5670E-02	9.9874E-01	-3.5197E-02
89	1.0652E-01	9.9074E-01	-2.0220E-01	9.5051E+00	9.7981E-03	1.0683E-01	9.9365E-01	-3.5197E-02
90	1.7692E-01	9.8061E-01	-2.0220E-01	9.5051E+00	9.7981E-03	1.7744E-01	9.8350E-01	-3.5197E-02
91	2.4643E-01	9.6549E-01	-2.0220E-01	9.5051E+00	9.7981E-03	2.4715E-01	9.6834E-01	-3.5197E-02
92	3.1468E-01	9.4545E-01	-2.0220E-01	9.5051E+00	9.7981E-03	3.1560E-01	9.4824E-01	-3.5197E-02
93	3.8132E-01	9.2060E-01	-2.0220E-01	9.5051E+00	9.7981E-03	3.8245E-01	9.2331E-01	-3.5197E-02
94	4.4603E-01	8.9105E-01	-2.0220E-01	9.5051E+00	9.7981E-03	4.4734E-01	8.9367E-01	-3.5197E-02

95	5.0846E-01	8.5696E-01	-2.0220E-01	9.5051E+00	9.7981E-03	5.0995E-01	8.5948E-01	-3.5197E-02
96	5.6830E-01	8.1850E-01	-2.0220E-01	9.5051E+00	9.7981E-03	5.6997E-01	8.2091E-01	-3.5197E-02
97	6.2524E-01	7.7587E-01	-2.0220E-01	9.5051E+00	9.7981E-03	6.2708E-01	7.7816E-01	-3.5197E-02
98	6.7900E-01	7.2929E-01	-2.0220E-01	9.5051E+00	9.7981E-03	6.8100E-01	7.3144E-01	-3.5197E-02
99	7.2929E-01	6.7900E-01	-2.0220E-01	9.5051E+00	9.7981E-03	7.3144E-01	6.8100E-01	-3.5197E-02
100	7.7587E-01	6.2524E-01	-2.0220E-01	9.5051E+00	9.7981E-03	7.7816E-01	6.2708E-01	-3.5197E-02
101	8.1850E-01	5.6830E-01	-2.0220E-01	9.5051E+00	9.7981E-03	8.2091E-01	5.6997E-01	-3.5197E-02
102	8.5696E-01	5.0846E-01	-2.0220E-01	9.5051E+00	9.7981E-03	8.5948E-01	5.0995E-01	-3.5197E-02
103	8.9105E-01	4.4603E-01	-2.0220E-01	9.5051E+00	9.7981E-03	8.9367E-01	4.4734E-01	-3.5197E-02
104	9.2060E-01	3.8132E-01	-2.0220E-01	9.5051E+00	9.7981E-03	9.2331E-01	3.8245E-01	-3.5197E-02
105	9.4545E-01	3.1468E-01	-2.0220E-01	9.5051E+00	9.7981E-03	9.4824E-01	3.1560E-01	-3.5197E-02
106	9.6549E-01	2.4643E-01	-2.0220E-01	9.5051E+00	9.7981E-03	9.6834E-01	2.4715E-01	-3.5197E-02
107	9.8061E-01	1.7692E-01	-2.0220E-01	9.5051E+00	9.7981E-03	9.8350E-01	1.7744E-01	-3.5197E-02
108	9.9074E-01	1.0652E-01	-2.0220E-01	9.5051E+00	9.7981E-03	9.9365E-01	1.0683E-01	-3.5197E-02
109	9.9581E-01	3.5565E-02	-2.0220E-01	9.5051E+00	9.7981E-03	9.9874E-01	3.5670E-02	-3.5197E-02
110	3.5679E-02	9.9898E-01	-6.6809E-02	1.0792E+01	9.5677E-03	3.5690E-02	9.9930E-01	-1.1599E-02
111	1.0685E-01	9.9389E-01	-6.6809E-02	1.0792E+01	9.5677E-03	1.0689E-01	9.9420E-01	-1.1599E-02
112	1.7748E-01	9.8373E-01	-6.6809E-02	1.0792E+01	9.5677E-03	1.7754E-01	9.8405E-01	-1.1599E-02
113	2.4721E-01	9.6856E-01	-6.6809E-02	1.0792E+01	9.5677E-03	2.4729E-01	9.6887E-01	-1.1599E-02
114	3.1568E-01	9.4846E-01	-6.6809E-02	1.0792E+01	9.5677E-03	3.1578E-01	9.4876E-01	-1.1599E-02
115	3.8254E-01	9.2352E-01	-6.6809E-02	1.0792E+01	9.5677E-03	3.8266E-01	9.2382E-01	-1.1599E-02
116	4.4744E-01	8.9388E-01	-6.6809E-02	1.0792E+01	9.5677E-03	4.4759E-01	8.9417E-01	-1.1599E-02

117	5.1007E-01	8.5968E-01	-6.6809E-02	1.0792E+01	9.5677E-03	5.1024E-01	8.5996E-01	-1.1599E-02
118	5.7010E-01	8.2110E-01	-6.6809E-02	1.0792E+01	9.5677E-03	5.7028E-01	8.2137E-01	-1.1599E-02
119	6.2723E-01	7.7834E-01	-6.6809E-02	1.0792E+01	9.5677E-03	6.2743E-01	7.7859E-01	-1.1599E-02
120	6.8115E-01	7.3161E-01	-6.6809E-02	1.0792E+01	9.5677E-03	6.8137E-01	7.3185E-01	-1.1599E-02
121	7.3161E-01	6.8115E-01	-6.6809E-02	1.0792E+01	9.5677E-03	7.3185E-01	6.8137E-01	-1.1599E-02
122	7.7834E-01	6.2723E-01	-6.6809E-02	1.0792E+01	9.5677E-03	7.7859E-01	6.2743E-01	-1.1599E-02
123	8.2110E-01	5.7010E-01	-6.6809E-02	1.0792E+01	9.5677E-03	8.2137E-01	5.7028E-01	-1.1599E-02
124	8.5968E-01	5.1007E-01	-6.6809E-02	1.0792E+01	9.5677E-03	8.5996E-01	5.1024E-01	-1.1599E-02
125	8.9388E-01	4.4744E-01	-6.6809E-02	1.0792E+01	9.5677E-03	8.9417E-01	4.4759E-01	-1.1599E-02
126	9.2352E-01	3.8254E-01	-6.6809E-02	1.0792E+01	9.5677E-03	9.2382E-01	3.8266E-01	-1.1599E-02
127	9.4846E-01	3.1568E-01	-6.6809E-02	1.0792E+01	9.5677E-03	9.4876E-01	3.1578E-01	-1.1599E-02
128	9.6856E-01	2.4721E-01	-6.6809E-02	1.0792E+01	9.5677E-03	9.6887E-01	2.4729E-01	-1.1599E-02
129	9.8373E-01	1.7748E-01	-6.6809E-02	1.0792E+01	9.5677E-03	9.8405E-01	1.7754E-01	-1.1599E-02
130	9.9389E-01	1.0685E-01	-6.6809E-02	1.0792E+01	9.5677E-03	9.9420E-01	1.0689E-01	-1.1599E-02
131	9.9898E-01	3.5678E-02	-6.6809E-02	1.0792E+01	9.5677E-03	9.9930E-01	3.5690E-02	-1.1599E-02

```
SURFACE NORMAL VELOCITY BOUNDARY CONDITION

                         SURFACE VELOCITIES(   REAL PART, IMAGINARY PART   )

REGION =  1
                  V(  1)
          0.          0.

REGION =  2
                  V(  2)                V( 10)                V( 18)                V( 26)
          0.          0.        0.          0.        0.          0.        0.          0.
                  V( 34)                V( 42)                V( 50)                V( 58)
          0.          0.        0.          0.        0.          0.        0.          0.

REGION =  3
                  V( 66)                V( 88)                V(110)
          1.0000E+00  0.        1.0000E+00  0.        1.0000E+00  0.
```

```
ENTER SUBROUTINE FOR ITERATIVE SOLUTION FOR SURFACE PRESSURE

 REQUESTED LIMIT ON NUMBER OF ITERATIONS =  30

 RELAXATION FACTOR SPECIFIED IS

   REAL PART  IMAGINARY PART
  5.0000E-01      0.

 CONVERGENCE CRITERION =  1.0000E-04


BEGIN ITERATION

 TIME =      3.499E+01 SECONDS

 MAXIMUM DIFFERENCE BETWEEN COMPONENTS

       OF SUCCESSIVE VECTORS
            7.4258E-01

            3.1473E-02

            2.9968E-02

            1.1865E-02

            5.8426E-03

            2.5022E-03

            9.7444E-04

            5.4539E-04

            2.7899E-04

            1.3924E-04

            7.1037E-05

 ITERATION TERMINATED BY CONVERGENCE CRITERION BEING MET


 TIME AT TERMINATION IS      3.543E+01 SECONDS


                                        SURFACE PRESSURES(   REAL PART, IMAGINARY PART   )


REGION =  1

                     P(  1)

              -1.3227E-01   9.5231E-02
```

```
REGION =  2

              P(  2)                  P( 10)                  P( 18)                  P( 26)

     -1.1544E-01   9.8167E-02   -6.1052E-02   1.3380E-01   3.0956E-02   1.5099E-01   1.2733E-01   1.3008E-01
              P( 34)                  P( 42)                  P( 50)                  P( 58)

      2.0521E-01   7.5974E-02    2.6928E-01  -1.4969E-03   3.1320E-01  -1.0025E-01   3.4371E-01  -2.3360E-01

REGION =  3

              P( 66)                  P( 88)                  P(110)

      3.5058E-01  -4.5764E-01    3.6265E-01  -5.4688E-01   3.6829E-01  -5.8323E-01


 RADIATION IMPEDANCE    REAL PART   IMAGINARY PART

                        3.6028E-01   -5.2768E-01

ELAPSED TIME AT EXIT FROM XMAVE =     3.547E+01  SECONDS
```

NUMERICAL CALCULATION OF INDUCED MASS

The third and final problem illustrates a numerical calculation of induced mass according to the method and formulation discussed in the section entitled OPTION FOR INDUCED MASS CALCULATION. The problem posed here is based on an earlier numerical investigation of the induced mass effect for cylinders in rigid body motion.*

We consider a cylinder of length 4.11 cm, radius 1.27 cm, and oriented with respect to coordinates as the cylinder in Figure 14. The cylinder vibrates perpendicular to its longitudinal axis with assumed velocity magnitude unity. This motion generates a normal surface velocity pattern which is symmetric with respect to the xz- and xy-planes and antisymmetric with respect to the yz-plane. We therefore specify, as in the first example problem, only an octant of the surface as a basis for generation of the acoustic model, Figure 15.

For the present calculation, the data specify a modeling of the end cap, Region 1, by six bands with nine stations per band and of the lateral surface, Region 2, by 12 bands each with nine stations. This gives an effective covering of the entire surface by $8 \times (6 \times 9 + 12 \times 9) = 1296$ elements. Thus for our purpose, we are using here a considerably less refined surface model than the 3456-element model used to obtain the previous results (CMD-41-71).

The input value $k = 0.00001$ is an approximation for the condition of fluid incompressibility. The fluid density is unity.

Option 4 (page 32) is selected to obtain automatic generation of the normal surface velocity at each station from the velocity magnitude specified for each region on the "NORMAL SURFACE VELOCITY" data cards. In the case of rigid body motion as considered here, the velocity data on these cards do not signify <u>normal</u> surface velocities but rather velocities in the direction of rigid body motion, from which normal components will be automatically generated.

The induced mass (in grams, since centimeter-gram-second system was used in data) obtained here is within 2.7 percent of the results obtained with the finer model.

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*See the double asterisk footnote on page 3.

ALL APPLICATIONS

TITLE EXAMPLE PROBLEM 3 DATE ______

PROBLEM ______ SHEET 1 OF 2

XWAVE DATA

PROBLEM TITLE

ΔΔΔΔΔΔΔΔΔΔΔΔFINITE CYLINDER, RADIUS, A=1.27, LENGTH, B=4.11

13 72

CASE TITLE

ΔΔΔΔΔΔΔΔΔΔΔΔINDUCED MASS FOR TRANSVERSE RIGID BODY MOTION

13 72

DIMENSIONS FOR XWAVE

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
0162	0004	0162	0002	0009									
1	5	9	13	17	21	25	29	33	37	41	45	49	53 56

MISCELLANEOUS DATA

k		c	ρ	H (REAL)	H (IMAG)	ITERATION LIMIT	CONVERGENCE CRITERION
ΔΔ1.0E-5	ΔΔΔΔΔΔΔΔ		1.0	0.5	0.0	0030	Δ1.0E-13
1	9	17	25	33	41	49	53 60

PROGRAM OPTIONS

OPT1	OPT2	OPT3	OPT4	OPT5	OPT6	OPT7	OPT8	OPT9	OPT10
0000	0001	0001	0003		0001		0001	0001	
1	5	9	13	17	21	25	29	33	37 40

SYMMETRY OPTIONS

YZ-PLANE	XZ-PLANE	LONG.	RADIAL
0003	0004	0001	
1	5	9	13 16

DATA INPUT FORM (1)

PIECEWISE CONICAL SHELL SURFACE

TITLE EXAMPLE PROBLEM 3 DATE ____

PROBLEM ____ SHEET 2 OF 2

XWAVE DATA

NUMBER OF REGIONS

0002

1 4

REGION: EXTENT AND MODELING

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
0.0	1.27	0.0	90.0	-2.055	-2.055	0006	0009	-1.0
1	9	17	25	33	41	49	53	57 64

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
0.0	∞	0.0
1 8	11	18

REGION: EXTENT AND MODELING

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1.27	1.27	0.0	90.0	-2.055	0.0	0012	0009	
1	9	17	25	33	41	49	53	57 64

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
1.0	∞	0.0
1 8	11	18

REGION: EXTENT AND MODELING

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 64

NORMAL SURFACE VELOCITY

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
	∞	
1 8	11	18

DATA INPUT FORM (2)

```
ELAPSED TIME AT ENTRY INTO XWAVE =     2.525E+01 SECONDS

THERE ARE 061026(OCTAL) WORDS OF OPEN-CORE AVAILABLE FOR THIS PROBLEM

CM REDUCED TO 051400(OCTAL)
```

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XWAVE  SEPTEMBER 1976

 FINITE CYLINDER, RADIUS,A=1.27, LENGTH,B=4.11
 INDUCED MASS FOR TRANSVERSE RIGID BODY MOTION

DIMENSIONS FOR ARRAYS

 DIMENSION  1 = 162
 DIMENSION  2 =   4
 DIMENSION  3 = 162
 DIMENSION  4 =   2
 DIMENSION  5 =   9
 DIMENSION  6 =   1
 DIMENSION  7 =   1
 DIMENSION  8 =   1
 DIMENSION  9 =   1
 DIMENSION 10 =   1
 DIMENSION 11 =   1
 DIMENSION 12 =   1
 DIMENSION 13 =   1
 DIMENSION 14 =   1

WAVE NUMBER K =  1.0000E-05

OPTION DATA
OP1  OP2  OP3  OP4  OP5  OP6  OP7  OP8  OP9  OP10
 0    1    1    3    0    1    0    1    1    0


FLUID MASS DENSITY =  1.0000E+00


SURFACE GEOMETRY AND BOUNDARY CONDITION SYMMETRIES

 YZ-PLANE ANTISYMMETRY

 XZ-PLANE SYMMETRY

 LONGITUDINAL SYMMETRY
```

SURFACE MODEL GEOMETRY

SURFACE ELEMENT NO.	ELEMENT BASE POINT COORDINATES X	Y	Z	INVERSE CURVATURE AT BASE POINT	AREA OF ELEMENT	COORDINATES OF UNIT OUTWARD NORMAL AT BASE POINT X	Y	Z
1	9.2240E-03	1.8543E-01	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
2	2.7392E-02	1.8223E-01	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
3	4.4727E-02	9.5918E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
4	6.0784E-02	8.6694E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
5	7.4835E-02	7.4835E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00

6	8.6694E-02	6.0704E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
7	9.5918E-02	4.4727E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
8	1.0223E-01	2.7392E-02	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
9	1.0543E-01	9.2240E-03	-2.0550E+00	0.	3.9098E-03	0.	0.	-1.0000E+00
10	2.7672E-02	3.1629E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
11	8.2175E-02	3.0668E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
12	1.3418E-01	2.8775E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
13	1.8211E-01	2.6088E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
14	2.2451E-01	2.2451E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
15	2.6088E-01	1.8211E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
16	2.8775E-01	1.3418E-01	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
17	3.0688E-01	8.2175E-02	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
18	3.1629E-01	2.7672E-02	-2.0550E+00	0.	1.1729E-02	0.	0.	-1.0000E+00
19	4.6120E-02	5.2715E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
20	1.3696E-01	5.1114E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
21	2.2364E-01	4.7959E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
22	3.0352E-01	4.3347E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
23	3.7418E-01	3.7418E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
24	4.3347E-01	3.0352E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
25	4.7959E-01	2.2364E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
26	5.1114E-01	1.3696E-01	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00
27	5.2715E-01	4.6120E-02	-2.0550E+00	0.	1.9549E-02	0.	0.	-1.0000E+00

28	6.4568E-02	7.3801E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
29	1.9174E-01	7.1559E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
30	3.1309E-01	6.7142E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
31	4.2492E-01	6.0686E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
32	5.2385E-01	5.2385E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
33	6.0686E-01	4.2492E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
34	6.7142E-01	3.1309E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
35	7.1559E-01	1.9174E-01	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
36	7.3801E-01	6.4568E-02	-2.0550E+00	0.	2.7368E-02	0.	0.	-1.0000E+00
37	8.3016E-02	9.4888E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
38	2.4653E-01	9.2084E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
39	4.0254E-01	8.6326E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
40	5.4633E-01	7.8024E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
41	6.7352E-01	6.7352E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
42	7.8024E-01	5.4633E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
43	8.6326E-01	4.0254E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
44	9.2084E-01	2.4653E-01	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
45	9.4888E-01	8.3016E-02	-2.0550E+00	0.	3.5188E-02	0.	0.	-1.0000E+00
46	2.0146E-01	1.1597E+00	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
47	3.0131E-01	1.1245E+00	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
48	4.9200E-01	1.0551E+00	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
49	6.6774E-01	9.5363E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00

50	8.2319E-01	8.2319E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
51	9.5363E-01	6.6774E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
52	1.0551E+00	4.9200E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
53	1.1245E+00	3.0131E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
54	1.1597E+00	1.0146E-01	-2.0550E+00	0.	4.3008E-02	0.	0.	-1.0000E+00
55	1.1069E-01	1.2652E+00	-1.9694E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
56	3.2870E-01	1.2267E+00	-1.9694E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
57	5.3673E-01	1.1510E+00	-1.9694E+00	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
58	7.2844E-01	1.0403E+00	-1.9694E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
59	8.9803E-01	8.9803E-01	-1.9694E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
60	1.0403E+00	7.2844E-01	-1.9694E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
61	1.1510E+00	5.3673E-01	-1.9694E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
62	1.2267E+00	3.2870E-01	-1.9694E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
63	1.2652E+00	1.1069E-01	-1.9694E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
64	1.1069E-01	1.2652E+00	-1.7981E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
65	3.2870E-01	1.2267E+00	-1.7981E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
66	5.3673E-01	1.1510E+00	-1.7981E+00	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
67	7.2844E-01	1.0403E+00	-1.7981E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
68	8.9803E-01	8.9803E-01	-1.7981E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
69	1.0403E+00	7.2844E-01	-1.7981E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
70	1.1510E+00	5.3673E-01	-1.7981E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
71	1.2267E+00	3.2870E-01	-1.7981E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.

72	1.2652E+00	1.1069E-01	-1.7981E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
73	1.1069E-01	1.2652E+00	-1.6269E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
74	3.2870E-01	1.2267E+00	-1.6269E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
75	5.3673E-01	1.1510E+00	-1.6269E+00	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
76	7.2844E-01	1.0403E+00	-1.6269E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
77	8.9803E-01	8.9803E-01	-1.6269E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
78	1.0403E+00	7.2844E-01	-1.6269E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
79	1.1510E+00	5.3673E-01	-1.6269E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
80	1.2267E+00	3.2870E-01	-1.6269E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
81	1.2652E+00	1.1069E-01	-1.6269E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
82	1.1069E-01	1.2652E+00	-1.4556E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
83	3.2870E-01	1.2267E+00	-1.4556E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
84	5.3673E-01	1.1510E+00	-1.4556E+00	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
85	7.2844E-01	1.0403E+00	-1.4556E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
86	8.9803E-01	8.9803E-01	-1.4556E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
87	1.0403E+00	7.2844E-01	-1.4556E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
88	1.1510E+00	5.3673E-01	-1.4556E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
89	1.2267E+00	3.2870E-01	-1.4556E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
90	1.2652E+00	1.1069E-01	-1.4556E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
91	1.1069E-01	1.2652E+00	-1.2844E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
92	3.2870E-01	1.2267E+00	-1.2844E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
93	5.3673E-01	1.1510E+00	-1.2844E+00	2.5400E+00	1.7959E-02	4.2262E-01	9.0631E-01	0.

94	7.2844E-01	1.0403E+00	-1.2844E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
95	8.9803E-01	8.9803E-01	-1.2844E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
96	1.0403E+00	7.2844E-01	-1.2844E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
97	1.1510E+00	5.3673E-01	-1.2844E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
98	1.2267E+00	3.2870E-01	-1.2844E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
99	1.2652E+00	1.1069E-01	-1.2844E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
100	1.1069E-01	1.2652E+00	-1.1131E+00	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
101	3.2870E-01	1.2267E+00	-1.1131E+00	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
102	5.3673E-01	1.1510E+00	-1.1131E+00	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
103	7.2844E-01	1.0403E+00	-1.1131E+00	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
104	8.9803E-01	8.9803E-01	-1.1131E+00	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
105	1.0403E+00	7.2844E-01	-1.1131E+00	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
106	1.1510E+00	5.3673E-01	-1.1131E+00	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
107	1.2267E+00	3.2870E-01	-1.1131E+00	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
108	1.2652E+00	1.1069E-01	-1.1131E+00	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
109	1.1069E-01	1.2652E+00	-9.4188E-01	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
110	3.2870E-01	1.2267E+00	-9.4188E-01	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
111	5.3673E-01	1.1510E+00	-9.4188E-01	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
112	7.2844E-01	1.0403E+00	-9.4188E-01	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
113	8.9803E-01	8.9803E-01	-9.4188E-01	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
114	1.0403E+00	7.2844E-01	-9.4188E-01	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
115	1.1510E+00	5.3673E-01	-9.4188E-01	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.

116	1.2287E+00	3.2870E-01	-9.4188E-01	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
117	1.2652E+00	1.1069E-01	-9.4188E-01	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
118	1.1069E-01	1.2652E+00	-7.7063E-01	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
119	3.2870E-01	1.2267E+00	-7.7063E-01	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
120	5.3673E-01	1.1510E+00	-7.7063E-01	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
121	7.2844E-01	1.0403E+00	-7.7063E-01	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
122	8.9803E-01	8.9803E-01	-7.7063E-01	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
123	1.0403E+00	7.2844E-01	-7.7063E-01	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
124	1.1510E+00	5.3673E-01	-7.7063E-01	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
125	1.2287E+00	3.2870E-01	-7.7063E-01	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
126	1.2652E+00	1.1069E-01	-7.7063E-01	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
127	1.1069E-01	1.2652E+00	-5.9938E-01	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
128	3.2870E-01	1.2267E+00	-5.9938E-01	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
129	5.3673E-01	1.1510E+00	-5.9938E-01	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
130	7.2844E-01	1.0403E+00	-5.9938E-01	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
131	8.9803E-01	8.9803E-01	-5.9938E-01	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
132	1.0403E+00	7.2844E-01	-5.9938E-01	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
133	1.1510E+00	5.3673E-01	-5.9938E-01	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
134	1.2287E+00	3.2870E-01	-5.9938E-01	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
135	1.2652E+00	1.1069E-01	-5.9938E-01	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
136	1.1069E-01	1.2652E+00	-4.2813E-01	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
137	3.2870E-01	1.2267E+00	-4.2813E-01	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.

138	5.3673E-01	1.1510E+00	-4.2813E-01	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
139	7.2844E-01	1.0403E+00	-4.2813E-01	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
140	8.9803E-01	8.9803E-01	-4.2813E-01	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
141	1.0403E+00	7.2844E-01	-4.2813E-01	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
142	1.1510E+00	5.3673E-01	-4.2813E-01	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
143	1.2267E+00	3.2870E-01	-4.2813E-01	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
144	1.2652E+00	1.1069E-01	-4.2813E-01	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
145	1.1069E-01	1.2652E+00	-2.5688E-01	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
146	3.2870E-01	1.2267E+00	-2.5688E-01	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
147	5.3673E-01	1.1510E+00	-2.5688E-01	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
148	7.2844E-01	1.0403E+00	-2.5688E-01	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
149	8.9803E-01	8.9803E-01	-2.5688E-01	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
150	1.0403E+00	7.2844E-01	-2.5688E-01	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.
151	1.1510E+00	5.3673E-01	-2.5688E-01	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
152	1.2267E+00	3.2870E-01	-2.5688E-01	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
153	1.2652E+00	1.1069E-01	-2.5688E-01	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.
154	1.1069E-01	1.2652E+00	-8.5625E-02	2.5400E+00	3.7959E-02	8.7156E-02	9.9619E-01	0.
155	3.2870E-01	1.2267E+00	-8.5625E-02	2.5400E+00	3.7959E-02	2.5882E-01	9.6593E-01	0.
156	5.3673E-01	1.1510E+00	-8.5625E-02	2.5400E+00	3.7959E-02	4.2262E-01	9.0631E-01	0.
157	7.2844E-01	1.0403E+00	-8.5625E-02	2.5400E+00	3.7959E-02	5.7358E-01	8.1915E-01	0.
158	8.9803E-01	8.9803E-01	-8.5625E-02	2.5400E+00	3.7959E-02	7.0711E-01	7.0711E-01	0.
159	1.0403E+00	7.2844E-01	-8.5625E-02	2.5400E+00	3.7959E-02	8.1915E-01	5.7358E-01	0.

160	1.1510E+00	5.3673E-01	-8.5625E-02	2.5400E+00	3.7959E-02	9.0631E-01	4.2262E-01	0.
161	1.2267E+00	3.2870E-01	-8.5625E-02	2.5400E+00	3.7959E-02	9.6593E-01	2.5882E-01	0.
162	1.2652E+00	1.1069E-01	-8.5625E-02	2.5400E+00	3.7959E-02	9.9619E-01	8.7156E-02	0.

SURFACE NORMAL VELOCITY BOUNDARY CONDITION

SURFACE VELOCITIES(REAL PART, IMAGINARY PART   )

```
REGION =  1
              V(  1)               V(  2)               V(  3)               V(  4)
      0.           0.      0.           0.      0.           0.      0.           0.
              V(  5)               V(  6)               V(  7)               V(  8)
      0.           0.      0.           0.      0.           0.      0.           0.
              V(  9)               V( 10)               V( 11)               V( 12)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 13)               V( 14)               V( 15)               V( 16)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 17)               V( 18)               V( 19)               V( 20)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 21)               V( 22)               V( 23)               V( 24)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 25)               V( 26)               V( 27)               V( 28)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 29)               V( 30)               V( 31)               V( 32)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 33)               V( 34)               V( 35)               V( 36)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 37)               V( 38)               V( 39)               V( 40)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 41)               V( 42)               V( 43)               V( 44)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 45)               V( 46)               V( 47)               V( 48)
      0.           0.      0.           0.      0.           0.      0.           0.
              V( 49)               V( 50)               V( 51)               V( 52)
      0.           0.      0.           0.      0.           0.      0.           0.
```

V(53)	V(54)
0. 0.	0. 0.

REGION = 2

V(55)	V(56)	V(57)	V(58)
8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.
V(59)	V(60)	V(61)	V(62)
7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.	9.6593E-01 0.
V(63)	V(64)	V(65)	V(66)
9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.
V(67)	V(68)	V(69)	V(70)
5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.
V(71)	V(72)	V(73)	V(74)
9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.
V(75)	V(76)	V(77)	V(78)
4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.
V(79)	V(80)	V(81)	V(82)
9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.
V(83)	V(84)	V(85)	V(86)
2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.
V(87)	V(88)	V(89)	V(90)
8.1315E-01 0.	9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.
V(91)	V(92)	V(93)	V(94)
8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.
V(95)	V(96)	V(97)	V(98)
7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.	9.6593E-01 0.
V(99)	V(100)	V(101)	V(102)
9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.
V(103)	V(104)	V(105)	V(106)
5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.
V(107)	V(108)	V(109)	V(110)
9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.
V(111)	V(112)	V(113)	V(114)
4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.

V(115)	V(116)	V(117)	V(118)
9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.
V(119)	V(120)	V(121)	V(122)
2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.
V(123)	V(124)	V(125)	V(126)
8.1915E-01 0.	9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.
V(127)	V(128)	V(129)	V(130)
8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.
V(131)	V(132)	V(133)	V(134)
7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.	9.6593E-01 0.
V(135)	V(136)	V(137)	V(138)
9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.	4.2262E-01 0.
V(139)	V(140)	V(141)	V(142)
5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.	9.0631E-01 0.
V(143)	V(144)	V(145)	V(146)
9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.	2.5882E-01 0.
V(147)	V(148)	V(149)	V(150)
4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.	8.1915E-01 0.
V(151)	V(152)	V(153)	V(154)
9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.	8.7156E-02 0.
V(155)	V(156)	V(157)	V(158)
2.5882E-01 0.	4.2262E-01 0.	5.7358E-01 0.	7.0711E-01 0.
V(159)	V(160)	V(161)	V(162)
8.1915E-01 0.	9.0631E-01 0.	9.6593E-01 0.	9.9619E-01 0.

```
ENTER SUBROUTINE FOR ITERATIVE SOLUTION FOR SURFACE PRESSURE

 REQUESTED LIMIT ON NUMBER OF ITERATIONS =  30

 RELAXATION FACTOR SPECIFIED IS

   REAL PART  IMAGINARY PART
  5.0000E-01      0.

 CONVERGENCE CRITERION =  1.0000E-13


BEGIN ITERATION

 TIME =       1.674E+02 SECONDS

 MAXIMUM DIFFERENCE BETWEEN COMPONENTS

       OF SUCCESSIVE VECTORS
              1.0644E-05

              7.1767E-07

              3.0733E-07

              1.4186E-07

              7.1221E-08

              3.8737E-08

              2.2496E-08

              1.3695E-08

              8.5999E-09

              5.5026E-09

              3.5611E-09

              2.3196E-09

              1.5165E-09

              9.9349E-10

              6.5162E-10

              4.2766E-10

              2.8077E-10

              1.8436E-10

              1.2137E-10

              7.9502E-11

              5.2238E-11
```

```
3.4283E-11
2.2512E-11
1.4782E-11
9.7057E-12
6.3725E-12
4.1838E-12
2.7468E-12
1.8033E-12
1.1838E-12

ITERATION TERMINATED BY LIMIT ON NO. OF ITERATIONS BEING MET

TIME AT TERMINATION IS       3.213E+02 SECONDS


                    SURFACE PRESSURES(   REAL PART, IMAGINARY PART    )

REGION =  1

          P(  1)                   P(  2)                   P(  3)                   P(  4)
1.7432E-15  -1.4462E-08   5.1765E-15  -4.2946E-08   8.4526E-15  -7.0126E-08   1.1472E-14  -9.5174E-08
          P(  5)                   P(  6)                   P(  7)                   P(  8)
1.4142E-14  -1.1733E-07   1.6383E-14  -1.3592E-07   1.8127E-14  -1.5038E-07   1.9319E-14  -1.6028E-07
          P(  9)                   P( 10)                   P( 11)                   P( 12)
1.9924E-14  -1.6530E-07   5.2581E-15  -4.4029E-08   1.5615E-14  -1.3075E-07   2.5497E-14  -2.1349E-07
          P( 13)                   P( 14)                   P( 15)                   P( 16)
3.4604E-14  -2.8975E-07   4.2660E-14  -3.5721E-07   4.9420E-14  -4.1381E-07   5.4678E-14  -4.5784E-07
          P( 17)                   P( 18)                   P( 19)                   P( 20)
5.8275E-14  -4.8796E-07   6.0101E-14  -5.0325E-07   8.8684E-15  -7.5704E-08   2.6336E-14  -2.2481E-07
          P( 21)                   P( 22)                   P( 23)                   P( 24)
4.3003E-14  -3.6709E-07   5.8364E-14  -4.9821E-07   7.1951E-14  -6.1420E-07   8.3352E-14  -7.1152E-07
          P( 25)                   P( 26)                   P( 27)                   P( 28)
9.2220E-14  -7.8723E-07   9.8287E-14  -8.3901E-07   1.0137E-13  -8.6531E-07   1.2677E-14  -1.1165E-07
          P( 29)                   P( 30)                   P( 31)                   P( 32)
3.7645E-14  -3.3155E-07   6.1470E-14  -5.4138E-07   8.3427E-14  -7.3475E-07   1.0285E-13  -9.0581E-07
```

P(33)	P(34)	P(35)	P(36)
1.1915E-13 -1.0493E-06	1.3182E-13 -1.1610E-06	1.4049E-13 -1.2374E-06	1.4490E-13 -1.2761E-06
P(37)	P(38)	P(39)	P(40)
1.6890E-14 -1.5596E-07	5.0158E-14 -4.6314E-07	8.1902E-14 -7.5625E-07	1.1116E-13 -1.0264E-06
P(41)	P(42)	P(43)	P(44)
1.3703E-13 -1.2653E-06	1.5875E-13 -1.4658E-06	1.7564E-13 -1.6218E-06	1.8719E-13 -1.7285E-06
P(45)	P(46)	P(47)	P(48)
1.9306E-13 -1.7826E-06	2.2470E-14 -2.1390E-07	6.6726E-14 -6.3519E-07	1.0896E-13 -1.0372E-06
P(49)	P(50)	P(51)	P(52)
1.4787E-13 -1.4077E-06	1.8230E-13 -1.7354E-06	2.1119E-13 -2.0103E-06	2.3365E-13 -2.2242E-06
P(53)	P(54)		
2.4903E-13 -2.3706E-06	2.5683E-13 -2.4448E-06		

REGION = 2

P(55)	P(56)	P(57)	P(58)
-4.7339E-14 -5.4534E-07	-1.4058E-13 -1.6194E-06	-2.2954E-13 -2.6443E-06	-3.1154E-13 -3.5889E-06
P(59)	P(60)	P(61)	P(62)
-3.8406E-13 -4.4244E-06	-4.4492E-13 -5.1255E-06	-4.9226E-13 -5.6708E-06	-5.2464E-13 -6.0438E-06
P(63)	P(64)	P(65)	P(66)
-5.4108E-13 -6.2332E-06	-4.2319E-14 -6.4292E-07	-1.2567E-13 -1.9092E-06	-2.0520E-13 -3.1175E-06
P(67)	P(68)	P(69)	P(70)
-2.7850E-13 -4.2311E-06	-3.4334E-13 -5.2161E-06	-3.9774E-13 -6.0426E-06	-4.4006E-13 -6.6855E-06
P(71)	P(72)	P(73)	P(74)
-4.6901E-13 -7.1253E-06	-4.8371E-13 -7.3486E-06	-3.8609E-14 -7.1314E-07	-1.1465E-13 -2.1178E-06
P(75)	P(76)	P(77)	P(78)
-1.8722E-13 -3.4580E-06	-2.5409E-13 -4.6932E-06	-3.1324E-13 -5.7858E-06	-3.6288E-13 -6.7026E-06
P(79)	P(80)	P(81)	P(82)
-4.0149E-13 -7.4157E-06	-4.2790E-13 -7.9036E-06	-4.4130E-13 -8.1512E-06	-3.6213E-14 -7.6387E-07
P(83)	P(84)	P(85)	P(86)
-1.0754E-13 -2.2684E-06	-1.7560E-13 -3.7040E-06	-2.3832E-13 -5.0271E-06	-2.9380E-13 -6.1974E-06
P(87)	P(88)	P(89)	P(90)
-3.4036E-13 -7.1794E-06	-3.7657E-13 -7.9433E-06	-4.0134E-13 -8.4658E-06	-4.1392E-13 -8.7311E-06

P(91)	P(92)	P(93)	P(94)
-3.4586E-14 -8.0214E-07	-1.0271E-13 -2.3821E-06	-1.6771E-13 -3.8896E-06	-2.2761E-13 -5.2789E-06
P(95)	P(96)	P(97)	P(98)
-2.8060E-13 -6.5079E-06	-3.2507E-13 -7.5391E-06	-3.5965E-13 -8.3413E-06	-3.8331E-13 -8.8899E-06
P(99)	P(100)	P(101)	P(102)
-3.9532E-13 -9.1685E-06	-3.3449E-14 -8.3161E-07	-9.9331E-14 -2.4696E-06	-1.6219E-13 -4.0325E-06
P(103)	P(104)	P(105)	P(106)
-2.2013E-13 -5.4729E-06	-2.7138E-13 -6.7470E-06	-3.1438E-13 -7.8161E-06	-3.4783E-13 -8.6477E-06
P(107)	P(108)	P(109)	P(110)
-3.7071E-13 -9.2165E-06	-3.8232E-13 -9.5053E-06	-3.2641E-14 -8.5444E-07	-9.6932E-14 -2.5373E-06
P(111)	P(112)	P(113)	P(114)
-1.5828E-13 -4.1432E-06	-2.1481E-13 -5.6231E-06	-2.6482E-13 -6.9322E-06	-3.0679E-13 -8.0306E-06
P(115)	P(116)	P(117)	P(118)
-3.3943E-13 -8.8850E-06	-3.6175E-13 -9.4695E-06	-3.7309E-13 -9.7662E-06	-3.2065E-14 -8.7199E-07
P(119)	P(120)	P(121)	P(122)
-9.5221E-14 -2.5895E-06	-1.5548E-13 -4.2283E-06	-2.1102E-13 -5.7386E-06	-2.6015E-13 -7.0746E-06
P(123)	P(124)	P(125)	P(126)
-3.0137E-13 -8.1956E-06	-3.3344E-13 -9.0676E-06	-3.5537E-13 -9.6641E-06	-3.6650E-13 -9.9669E-06
P(127)	P(128)	P(129)	P(130)
-3.1658E-14 -8.8518E-07	-9.4014E-14 -2.6287E-06	-1.5351E-13 -4.2923E-06	-2.0835E-13 -5.8254E-06
P(131)	P(132)	P(133)	P(134)
-2.5685E-13 -7.1816E-06	-2.9755E-13 -8.3196E-06	-3.2921E-13 -9.2048E-06	-3.5086E-13 -9.8103E-06
P(135)	P(136)	P(137)	P(138)
-3.6186E-13 -1.0118E-05	-3.1382E-14 -8.9463E-07	-9.3191E-14 -2.6567E-06	-1.5217E-13 -4.3380E-06
P(139)	P(140)	P(141)	P(142)
-2.0652E-13 -5.8876E-06	-2.5460E-13 -7.2582E-06	-2.9495E-13 -8.4083E-06	-3.2633E-13 -9.3030E-06
P(143)	P(144)	P(145)	P(146)
-3.4780E-13 -9.9149E-06	-3.5869E-13 -1.0226E-05	-3.1209E-14 -9.0072E-07	-9.2680E-14 -2.6748E-06
P(147)	P(148)	P(149)	P(150)
-1.5133E-13 -4.3676E-06	-2.0539E-13 -5.9277E-06	-2.5321E-13 -7.3077E-06	-2.9333E-13 -8.4656E-06

P(151)	P(152)	P(153)	P(154)
-3.2454E-13 -9.3663E-06	-3.4589E-13 -9.9824E-06	-3.5672E-13 -1.0295E-05	-3.1127E-14 -9.0371E-07
P(155)	P(156)	P(157)	P(158)
-9.2434E-14 -2.6837E-05	-1.5093E-13 -4.3821E-06	-2.0485E-13 -5.9473E-06	-2.5253E-13 -7.3319E-06
P(159)	P(160)	P(161)	P(162)
-2.9255E-13 -8.4937E-06	-3.2368E-13 -9.3974E-06	-3.4497E-13 -1.0016E-05	-3.5570E-13 -1.0329E-05

INDUCED MASS OF FLUID = 1.5067E+01

ELAPSED TIME AT EXIT FROM XWAVE = 3.217E+02 SECONDS

AD-A042 663 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 20/1
A GUIDE TO USE OF THE XWAVE PROGRAM. PART I. RADIATED PRESSURES--ETC(U)
JUL 77 F M HENDERSON
UNCLASSIFIED DTNSRDC-77-0041-PT-1 NL

2 OF 2
ADA042 663

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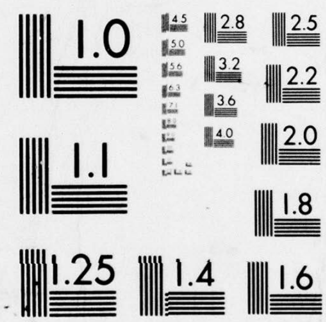

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX

XWAVE DATA INPUT FORMS

ALL APPLICATIONS

TITLE ______ DATE ______

PROBLEM ______ SHEET ______ OF ______

XWAVE DATA

PROBLEM TITLE

ΔΔΔΔΔΔΔΔΔΔΔΔ

13 72

CASE TITLE

ΔΔΔΔΔΔΔΔΔΔΔΔ

13 72

DIMENSIONS FOR XWAVE

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14

1 5 9 13 17 21 25 29 33 37 41 45 49 53 56

MISCELLANEOUS DATA

k	ΔΔΔΔΔΔΔΔ	c	ρ	H (REAL)	H (IMAG)	ITERATION LIMIT	CONVERGENCE CRITERION

1 9 17 25 33 41 49 53 60

PROGRAM OPTIONS

OPT1	OPT2	OPT3	OPT4	OPT5	OPT6	OPT7	OPT8	OPT9	OPT10

1 5 9 13 17 21 25 29 33 37 40

SYMMETRY OPTIONS

YZ-PLANE	XZ-PLANE	LONG.	RADIAL

1 5 9 13 16

DATA INPUT FORM (1)

PIECEWISE CONICAL SHELL SURFACE

TITLE ________________ DATE ________

PROBLEM ________________ SHEET ______ OF ______

XWAVE DATA

NUMBER OF REGIONS ________________

1 4

REGION: EXTENT AND MODELING ________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 (–64)

NORMAL SURFACE VELOCITY ________________

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
1	8	11 (–18)

REGION: EXTENT AND MODELING ________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 (–64)

NORMAL SURFACE VELOCITY ________________

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
1	8	11 (–18)

REGION: EXTENT AND MODELING ________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 (–64)

NORMAL SURFACE VELOCITY ________________

$\bar{V}_n$ (REAL)		$\bar{V}_n$ (IMAG.)
1	8	11 (–18)

DATA INPUT FORM (2)

PIECEWISE CONICAL SHELL SURFACE
(CONTINUATION SHEET)

TITLE ______________________ DATE ____________

PROBLEM ______________________ SHEET ______ OF ______

XWAVE DATA

REGION: EXTENT AND MODELING ______________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 – 64

NORMAL SURFACE VELOCITY ______________________

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8 ΔΔ	11 – 18

REGION: EXTENT AND MODELING ______________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 – 64

NORMAL SURFACE VELOCITY ______________________

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8 ΔΔ	11 – 18

REGION: EXTENT AND MODELING ______________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 – 64

NORMAL SURFACE VELOCITY ______________________

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8 ΔΔ	11 – 18

REGION: EXTENT AND MODELING ______________________

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN
1	9	17	25	33	41	49	53	57 – 64

NORMAL SURFACE VELOCITY ______________________

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8 ΔΔ	11 – 18

DATA INPUT FORM (3)

PIECEWISE CONICAL SHELL SURFACE WITH ASSUMED VELOCITY DISTRIBUTION (SEE PAGE 20)

TITLE ______ DATE ______

PROBLEM ______ SHEET ______ OF ______

XWAVE DATA

NUMBER OF REGIONS ______

1	4

PARAMETER CARD "A" FOR ASSUMED VELOCITY DISTRIBUTION ______

V_o(REAL)	V_o(IMAG.)	M	
1	7	13	16

REGION: EXTENT AND MODELING ______

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN	
1	9	17	25	33	41	49	53	57	64

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______

$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	
1	7	13	19	25	31	37	43	49	55	61	67	72 *

REGION: EXTENT AND MODELING ______

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN	
1	9	17	25	33	41	49	53	57	64

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______

$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	
1	7	13	19	25	31	37	43	49	55	61	67	72 *

DATA INPUT FORM (4)

* CONTINUATION CARDS AS NEEDED

PIECEWISE CONICAL SHELL SURFACE WITH ASSUMED VELOCITY DISTRIBUTION
(CONTINUATION SHEET)

TITLE ______________ DATE ______

PROBLEM ______________ SHEET ____ OF ____

XWAVE DATA

REGION: EXTENT AND MODELING ______

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN	
1	9	17	25	33	41	49	53	57	64

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______

$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	
1	7	13	19	25	31	37	43	49	55	61	67	72

REGION: EXTENT AND MODELING ______

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN	
1	9	17	25	33	41	49	53	57	64

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______

$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	
												*
1	7	13	19	25	31	37	43	49	55	61	67	72

REGION: EXTENT AND MODELING ______

r_1	r_2	θ_1	θ_2	z_1	z_2	n	m	SIGN	
1	9	17	25	33	41	49	53	57	64

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______

$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	
												*
1	7	13	19	25	31	37	43	49	55	61	67	72

* CONTINUATION CARDS AS NEEDED

DATA INPUT FORM (5)

PROLATE SPHEROIDAL SHELL SURFACE

TITLE ______________________ DATE ________

PROBLEM ______________________ SHEET ______ OF ______

XWAVE DATA

ELLIPSE SEMI-AXIS SPECIFICATION

$\overline{AA}$	$\overline{BB}$
1	9 – 16

NUMBER OF REGIONS

1 – 4

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 – 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 – 18

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 – 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 – 18

REGION: EXTENT AND MODELING

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 – 56

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 – 18

DATA INPUT FORM (6)

SPHERICAL SHELL SURFACE

TITLE ______ DATE ______

PROBLEM ______ SHEET ______ OF ______

XWAVE DATA

SPHERE RADIUS SPECIFICATION ______

RADIUS

1 8

NUMBER OF REGIONS ______

1 4

REGION: EXTENT AND MODELING ______

θ_1 θ_2 ϕ_1 ϕ_2 n m

1 9 17 25 33 41 49 53 56

NORMAL SURFACE VELOCITY ______

$\bar{V}_n$ (REAL) $\bar{V}_n$ (IMAG.)

1 8 11 18

REGION: EXTENT AND MODELING ______

θ_1 θ_2 ϕ_1 ϕ_2 n m

1 9 17 25 33 41 49 53 56

NORMAL SURFACE VELOCITY ______

$\bar{V}_n$ (REAL) $\bar{V}_n$ (IMAG.)

1 8 11 18

REGION: EXTENT AND MODELING ______

θ_1 θ_2 ϕ_1 ϕ_2 n m

1 9 17 25 33 41 49 53 56

NORMAL SURFACE VELOCITY ______

$\bar{V}_n$ (REAL) $\bar{V}_n$ (IMAG.)

1 8 11 18

DATA INPUT FORM (7)

PROLATE SPHEROIDAL SHELL SURFACE OR SPHERICAL SHELL SURFACE
(CONTINUATION SHEET)

TITLE ____________ DATE ____________

PROBLEM ____________ SHEET ______ OF ______

XWAVE DATA

REGION: EXTENT AND MODELING ____________

ΔΔΔΔΔΔΔΔ	ΔΔΔΔΔΔΔΔ	θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY ____________

$\bar{V}_n$ (REAL)	ΔΔ	$\bar{V}_n$ (IMAG.)
1	8	11 18

REGION: EXTENT AND MODELING ____________

ΔΔΔΔΔΔΔΔ	ΔΔΔΔΔΔΔΔ	θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY ____________

$\bar{V}_n$ (REAL)	ΔΔ	$\bar{V}_n$ (IMAG.)
1	8	11 18

REGION: EXTENT AND MODELING ____________

ΔΔΔΔΔΔΔΔ	ΔΔΔΔΔΔΔΔ	θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY ____________

$\bar{V}_n$ (REAL)	ΔΔ	$\bar{V}_n$ (IMAG.)
1	8	11 18

REGION: EXTENT AND MODELING ____________

ΔΔΔΔΔΔΔΔ	ΔΔΔΔΔΔΔΔ	θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

NORMAL SURFACE VELOCITY ____________

$\bar{V}_n$ (REAL)	ΔΔ	$\bar{V}_n$ (IMAG.)
1	9	11 18

DATA INPUT FORM (8)

PROLATE SPHEROIDAL SURFACE WITH ASSUMED VELOCITY DISTRIBUTION (SEE PAGE 20)

TITLE ______________________ DATE __________

PROBLEM ______________________ SHEET ______ OF ______

XWAVE DATA

ELLIPSE SEMI-AXIS SPECIFICATION ______

AA	BB
1	9 16

NUMBER OF REGIONS ______

1 4

PARAMETER CARD 'A' FOR ASSUMED VELOCITY DISTRIBUTION ______

V_o(REAL)	V_o(IMAG.)	M
1	7	13 16

REGION: EXTENT AND MODELING ______

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______ *

$R\psi(Z)_1$	$\ell\psi(Z)_1$	$R\psi(Z)_2$	$\ell\psi(Z)_2$	$R\psi(Z)_3$	$\ell\psi(Z)_3$	$R\psi(Z)_4$	$\ell\psi(Z)_4$	$R\psi(Z)_5$	$\ell\psi(Z)_5$	$R\psi(Z)_6$	$\ell\psi(Z)_6$
1	7	13	19	25	31	37	43	49	55	61	67 72

REGION: EXTENT AND MODELING ______

		θ_1	θ_2	ϕ_1	ϕ_2	n	m
1	9	17	25	33	41	49	53 56

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ______ *

$R\psi(Z)_1$	$\ell\psi(Z)_1$	$R\psi(Z)_2$	$\ell\psi(Z)_2$	$R\psi(Z)_3$	$\ell\psi(Z)_3$	$R\psi(Z)_4$	$\ell\psi(Z)_4$	$R\psi(Z)_5$	$\ell\psi(Z)_5$	$R\psi(Z)_6$	$\ell\psi(Z)_6$
1	7	13	19	25	31	37	43	49	55	61	67 72

* CONTINUATION CARDS AS NEEDED

DATA INPUT FORM (9)

PROLATE SPHEROIDAL SURFACE WITH ASSUMED VELOCITY DISTRIBUTION
(CONTINUATION SHEET)

TITLE ____________________ DATE __________

PROBLEM ____________________ SHEET ______ OF ______

XWAVE DATA

REGION: EXTENT AND MODELING ____________________

1	9	17	25	33	41	49	53	56
		θ_1	θ_2	ϕ_1	ϕ_2	n	m	

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ____________________

1	7	13	19	25	31	37	43	49	55	61	67	72
$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	*

REGION: EXTENT AND MODELING ____________________

1	9	17	25	33	41	49	53	56
		θ_1	θ_2	ϕ_1	ϕ_2	n	m	

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ____________________

1	7	13	19	25	31	37	43	49	55	61	67	72
$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	*

REGION: EXTENT AND MODELING ____________________

1	9	17	25	33	41	49	53	56
		θ_1	θ_2	ϕ_1	ϕ_2	n	m	

PARAMETER CARD 'B' FOR ASSUMED VELOCITY DISTRIBUTION ____________________

1	7	13	19	25	31	37	43	49	55	61	67	72
$R\,\psi(Z)_1$	$\ell\,\psi(Z)_1$	$R\,\psi(Z)_2$	$\ell\,\psi(Z)_2$	$R\,\psi(Z)_3$	$\ell\,\psi(Z)_3$	$R\,\psi(Z)_4$	$\ell\,\psi(Z)_4$	$R\,\psi(Z)_5$	$\ell\,\psi(Z)_5$	$R\,\psi(Z)_6$	$\ell\,\psi(Z)_6$	*

* CONTINUATION CARDS AS NEEDED

DATA INPUT FORM (10)

ARBITRARY SHELL SURFACE

TITLE ______________________ DATE ________

PROBLEM ______________________ SHEET ______ OF ______

XWAVE DATA

SURFACE GEOMETRIC DATA

STATION NO.	AREA	$X_{BASE\ POINT}$	$Y_{BASE\ POINT}$	$Z_{BASE\ POINT}$	n_x	n_y	n_z	CURVATURE
1	9	17	25	33	41	49	57	65 — 72

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 — 18

SURFACE GEOMETRIC DATA

STATION NO.	AREA	$X_{BASE\ POINT}$	$Y_{BASE\ POINT}$	$Z_{BASE\ POINT}$	n_x	n_y	n_z	CURVATURE
1	9	17	25	33	41	49	57	65 — 72

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 — 18

SURFACE GEOMETRIC DATA

STATION NO.	AREA	$X_{BASE\ POINT}$	$Y_{BASE\ POINT}$	$Z_{BASE\ POINT}$	n_x	n_y	n_z	CURVATURE
1	9	17	25	33	41	49	57	65 — 72

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 — 18

SURFACE GEOMETRIC DATA

STATION NO.	AREA	$X_{BASE\ POINT}$	$Y_{BASE\ POINT}$	$Z_{BASE\ POINT}$	n_x	n_y	n_z	CURVATURE
1	9	17	25	33	41	49	57	65 — 72

NORMAL SURFACE VELOCITY

$\bar{V}_n$(REAL)		$\bar{V}_n$(IMAG.)
1	8	11 — 18

DATA INPUT FORM (11)

STRUCTURE-FLUID INTERACTION APPLICATIONS

TITLE __________ DATE __________

PROBLEM __________ SHEET _____ OF _____

XWAVE DATA

IN-VACUO NORMAL SURFACE VELOCITIES __________

$\bar{U}_n$(REAL)	$\bar{U}_n$(IMAG.)
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18
1 – 8	11 – 18

DATA INPUT FORM (12)

STRUCTURE-FLUID INTERACTION APPLICATIONS

TITLE ________________________ DATE ____________

PROBLEM ________________________ SHEET ______ OF ______

XWAVE DATA

IN-VACUO SURFACE MOBILITY COEFFICIENTS ____________

	Columns 1–16	Columns 17–32	Columns 33–48	Columns 49–64
FIRST COLUMN OF $[q_{ij}]$	q_{11}(REAL)	q_{11}(IMAG.)	q_{21}(REAL)	q_{21}(IMAG.)
	q_{31}(REAL)	q_{31}(IMAG.)	q_{41}(REAL)	q_{41}(IMAG.)
	$\vdots$ $q_{N-1,1}$(REAL)	$\vdots$ $q_{N-1,1}$(IMAG.)	$\vdots$ $q_{N,1}$(REAL)	$\vdots$ $q_{N,1}$(IMAG.)
SECOND COLUMN OF $[q_{ij}]$	q_{12}(REAL)	q_{12}(IMAG.)	q_{22}(REAL)	q_{22}(IMAG.)
	q_{32}(REAL)	q_{32}(IMAG.)	q_{42}(REAL)	q_{42}(IMAG.)
	$\vdots$ $q_{N-1,2}$(REAL)	$\vdots$ $q_{N-1,2}$(IMAG.)	$\vdots$ $q_{N,2}$(REAL)	$\vdots$ $q_{N,2}$(IMAG.)
	$\vdots$ $q_{1,N}$(REAL)	$\vdots$ $q_{1,N}$(IMAG.)	$\vdots$ $q_{2,N}$(REAL)	$\vdots$ $q_{2,N}$(IMAG.)
N^{th} COLUMN OF $[q_{ij}]$	$q_{3,N}$(REAL)	$q_{3,N}$(IMAG.)	$q_{4,N}$(REAL)	$q_{4,N}$(IMAG.)
	$\vdots$ $q_{N-1,N}$(REAL)	$\vdots$ $q_{N-1,N}$(IMAG.)	$\vdots$ $q_{N,N}$(REAL)	$\vdots$ $q_{N,N}$(IMAG.)

DATA INPUT FORM (13)

NEAR-OR INTERMEDIATE-FIELD PRESSURE CALCULATION

TITLE ______________________________ DATE ____________

PROBLEM ______________________________ SHEET ______ OF ______

XWAVE DATA

AUTOMATIC FIELD POINT GENERATION

NFLAT	NFLNG		LAT 1	LAT 2	LONG 1	LONG 2	RADIUS
		ΔΔΔ					
1	4	7	10	18	26	34	42 49

ARBITRARY FIELD POINT SPECIFICATION

X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24
X_F	Y_F	Z_F
1	9	17 24

DATA INPUT FORM (14)

FAR-FIELD PRESSURE CALCULATION

TITLE ______________________ DATE ______________

PROBLEM ______________________ SHEET ______ OF ______

XWAVE DATA

AUTOMATIC FAR-FIELD POINT GENERATION ______________________

NFFLAT	NFFLNG		LATLIM	LONGLIM
1	4	7	10	18	25

ARBITRARY FAR-FIELD POINT SPECIFICATION ______________________

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

ψ_{FF}	ϕ_{FF}
1	9	16

DATA INPUT FORM (15)

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